‘Societal applications of S2S forecast of IMD

M. Mohapatra

Virtual International Conference on the "Future directions of Subseasonal to Seasonal Prediction over South Asia" during 29-31 March 2021 at IITM, Pune, India

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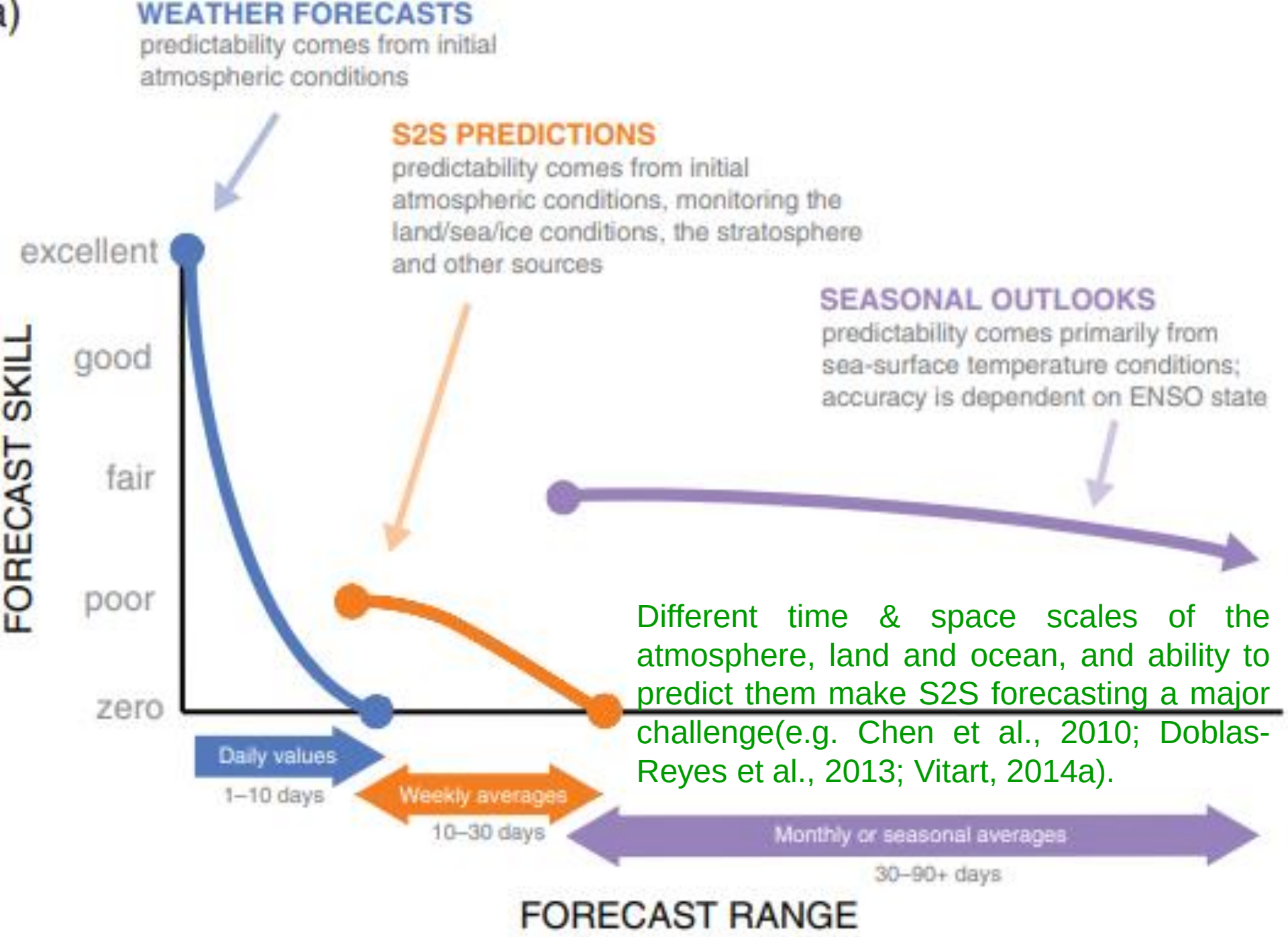
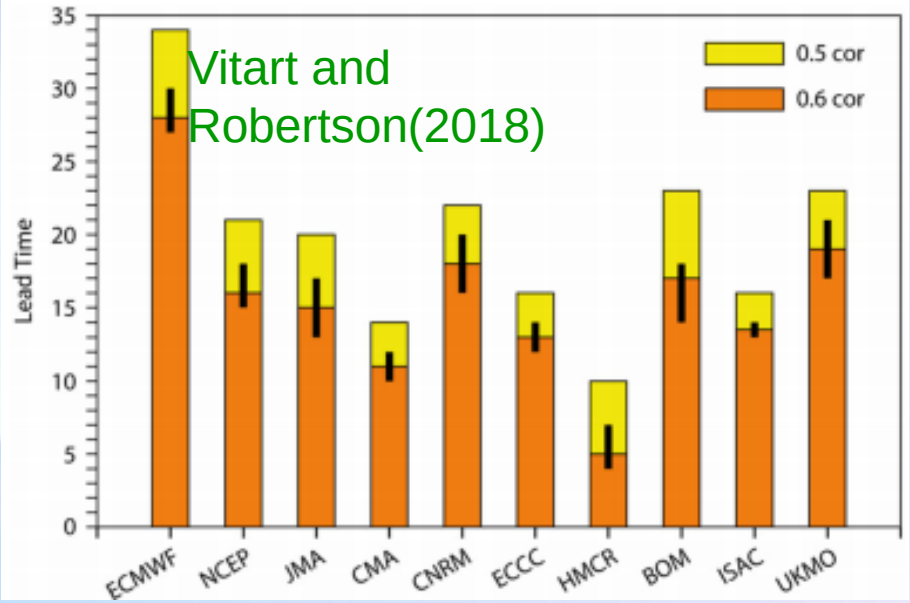


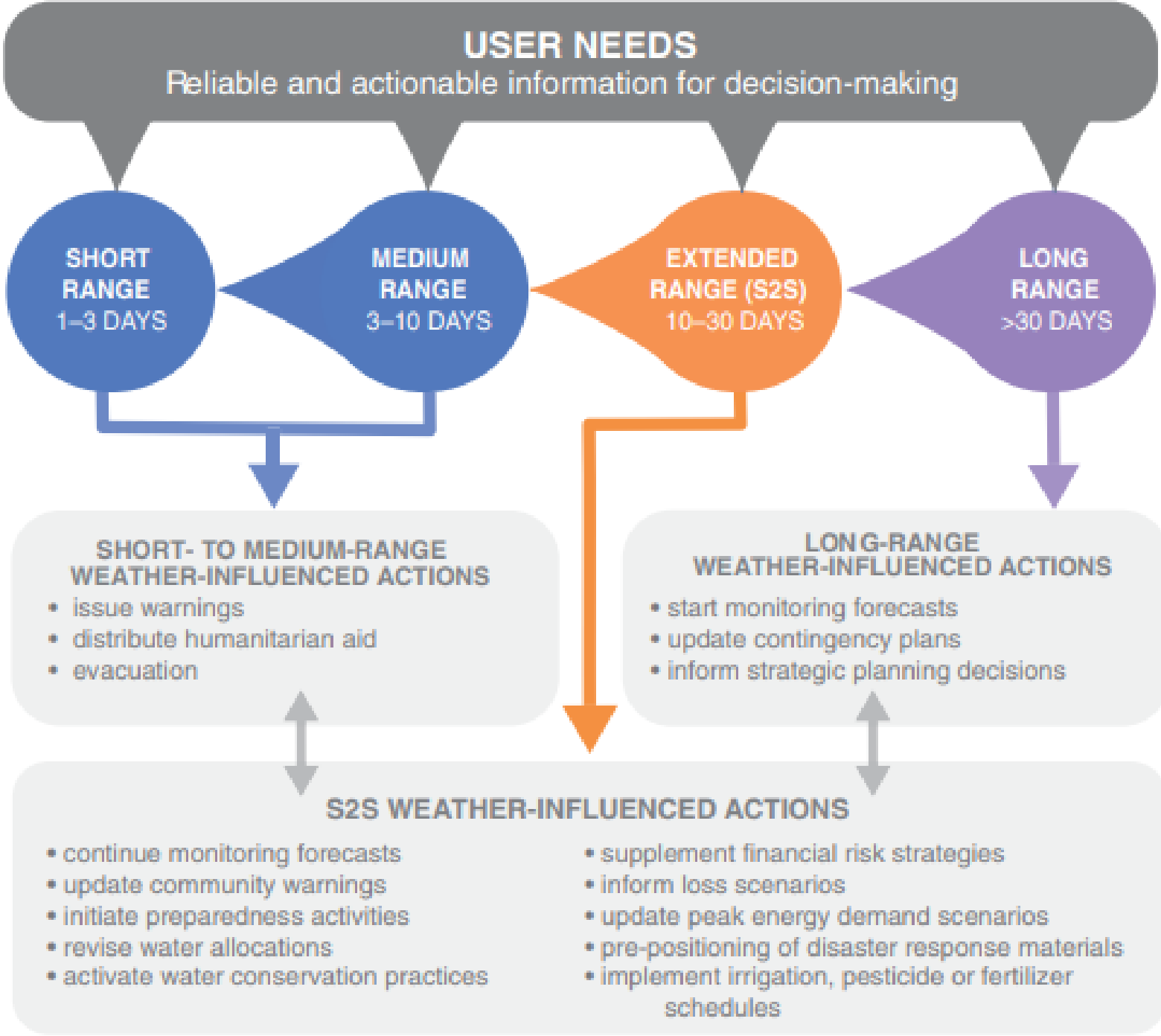
Different time & space scales of the atmosphere, land and ocean, and ability to predict them make S2S forecasting a major challenge(e.g. Chen et al., 2010; Doblas-Reyes et al., 2013; Vitart, 2014a).

Issues with Processes associated with S2S Prediction

- Like seasonal forecasting, S2S predictive skill relies on more than just realistic initialization conditions and SST,
- It depends on large-scale circulation modes in climate system, like
  - ❖ El Niño–Southern Oscillation (ENSO), Indian Ocean Dipole
  - ❖ Madden–Julian Oscillation (MJO), North Atlantic Oscillation,
- Their known influence on weather phenomena including extreme events.
- Forecast of such oscillation mode is still challenging
- MJO forecast skill.

Forecast lead time (days) when the MJO bivariate correlation reaches 0.5 (yellow bars) or 0.6 (orange bars) for 10 model re-forecasts covering the common period 1999–2010. The black vertical bars represent the 10% level of confidence for a bivariate correlation of 0.6 using a 10,000 resampling bootstrap technique




USER NEEDS
Reliable and actionable information for decision-making
SHORT RANGE
1–3 DAYS
MEDIUM RANGE
3–10 DAYS
EXTENDED RANGE (S2S)
10–30 DAYS
LONG RANGE
>30 DAYS
SHORT- TO MEDIUM-RANGE WEATHER-INFLUENCED ACTIONS
• issue warnings
• distribute humanitarian aid
• evacuation
LONG-RANGE WEATHER-INFLUENCED ACTIONS
• start monitoring forecasts
• update contingency plans
• inform strategic planning decisions
S2S WEATHER-INFLUENCED ACTIONS
• continue monitoring forecasts
• update community warnings
• initiate preparedness activities
• revise water allocations
• activate water conservation practices
• supplement financial risk strategies
• inform loss scenarios
• update peak energy demand scenarios
• pre-positioning of disaster response materials
• implement irrigation, pesticide or fertilizer schedules

Priorities Areas of S2S Applications

The five priority areas that may become vulnerable to climate change are:-

- **Disaster Risk management**
- **Agriculture and Food Security,**
- **Water availability and use**
- **Human Health impacts**
- **Energy availability and use**

Climate services framework is basically proposed to enable better management of the risks arising due to climate variability and change and appropriate adaptation strategy to climate change

IMD's Operational Extended Range Forecast (ERF) System

Atmospheric ICs
NCMRWF

Current week **Forecast run** for 32 days
based on Wednesday day ICs

Total 16 ensemble members
(1 control + 3 perturbed) each
CFSv2_T126 (4 mem)
CFSv2_T382 (4 mem)
GFSv2bc_T126 (4 mem)
GFSv2bc_T382 (4 mem)
(Based on Wednesday ICs)

Ocean ICs - INCOIS

Atmospheric ICs
NCMRWF

13 years **Hindcast run** for 32 days
(2003 to 2015) based on same date ICs

Total 16 ensemble members
(1 control + 3 perturbed) each
CFSv2_T126 (4 mem)
CFSv2_T382 (4 mem)
GFSv2bc_T126 (4 mem)
GFSv2bc_T382 (4 mem)
(Based on Corresponding Date ICs)

Ocean ICs - INCOIS

Bias Corrected Forecasts for 4 weeks

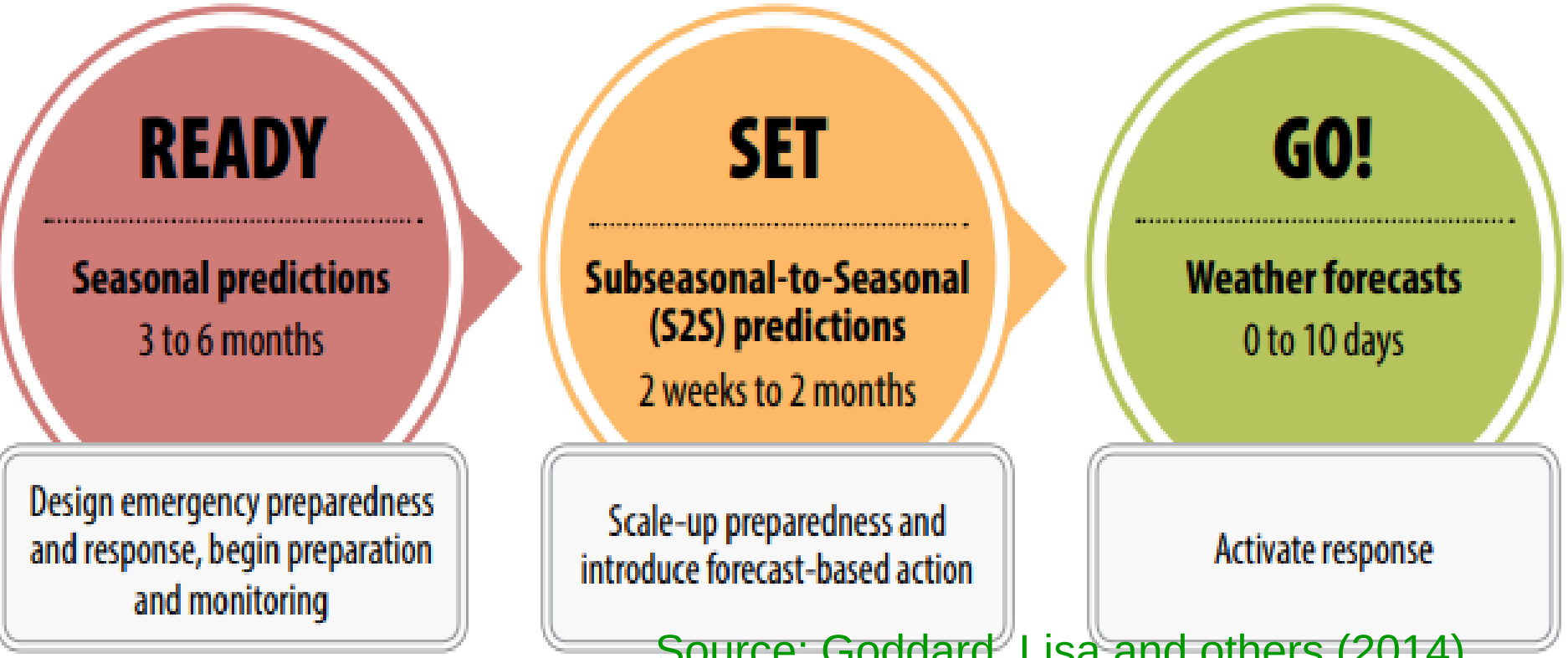
(Wind, Rainfall, Tmax and Tmin)
and its anomaly
Friday to Thursday

Week 1 : (Days 03-09)
Week 2 : (Days 10-16)
Week 3 : (Days 17-23)
Week 4 : (Days 24-30)

S2S Prediction for DRR

- S2S forecasts offer opportunity for DRR managers to track progress of the slowly evolving, large-scale climate modes that may have been predicted to shift in a preceding seasonal outlook, therefore supporting the transition from seasonal outlooks to weather forecasts to inform both disaster planning and systematic response (Tadesse et al., 2016).

'Ready', 'Set', 'Go!' decision structure developed by IFRC Climate Centre



Source: Goddard, Lisa and others (2014).

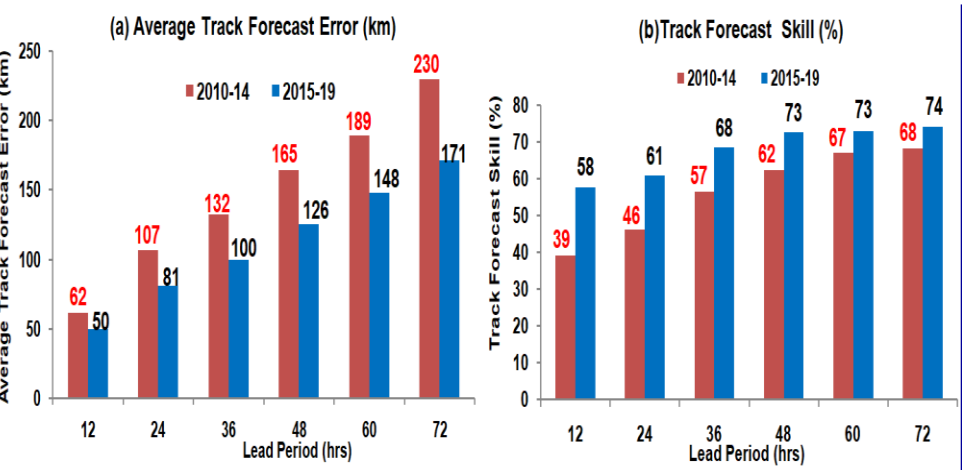
S2S Prediction for DRR

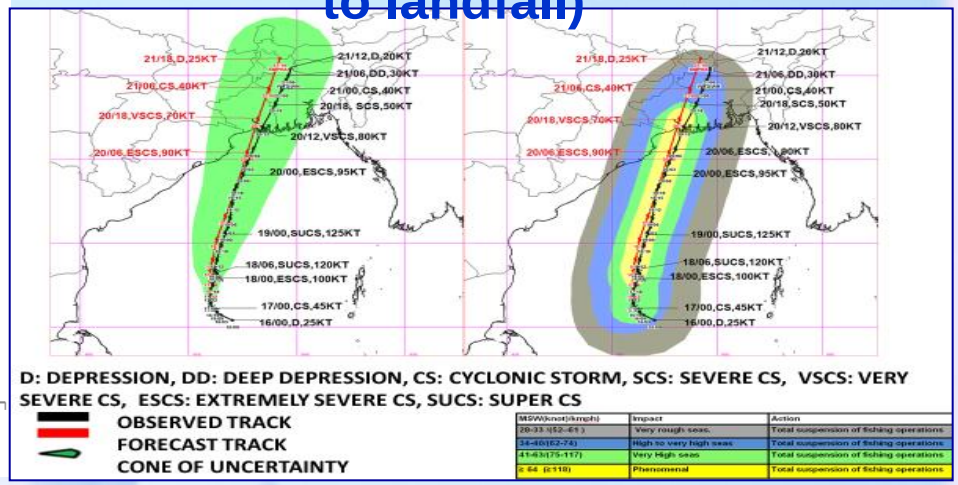
- DRR plans like
  - ❖ Heat/cold wave early warning plans
  - ❖ Flood/Drought preparedness plans
  - ❖ cyclone preparedness plans
  - ❖ Heavy rainfall warning plans
- could be expanded to include ‘Ready’ actions within the S2S timescale.
- The Sendai Framework for DRR 2015–2030 (UNISDR, 2015) points to to connect joint weather and climate communities’ efforts surrounding S2S prediction to global DRR activities and planning, as well as using seamless forecasting and climate service approaches.

Current Forecasting and warning skill of IMD

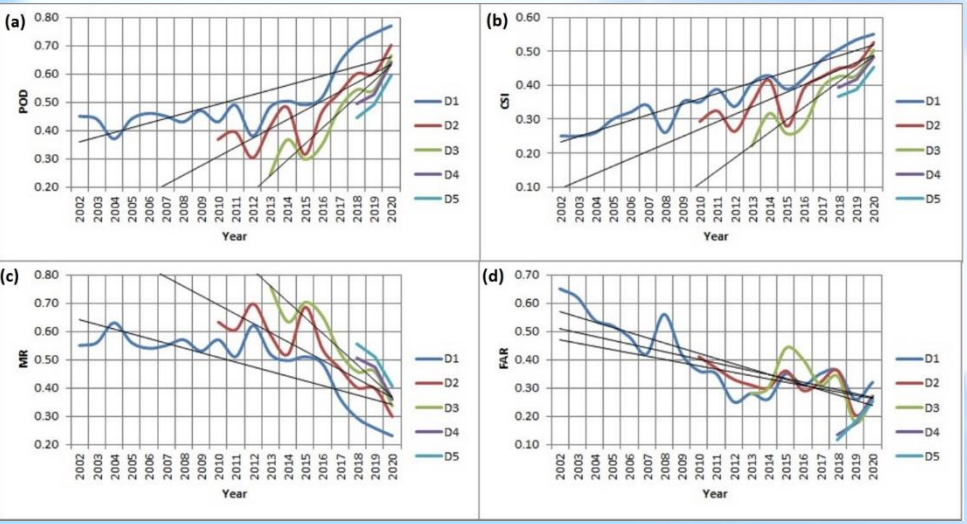
Cyclone Warning Skill

Based on 17/0600 UTC (84 hrs prior to landfall)





Monsoonal Heavy Rainfall Warning Skill



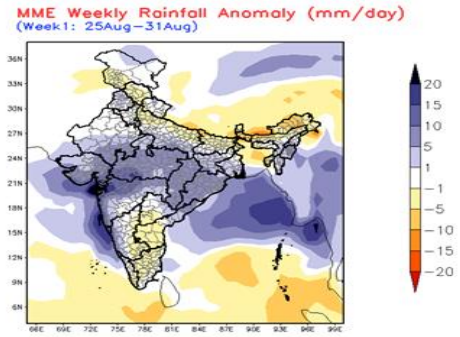
Heat Wave Warning Skill

All India	FAR			MR			CSI			POD		
	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
2017	.07	.06	.02	.33	.51	.77	.40	.32	.19	.67	.49	.23
2018	.03	.04	.02	.09	.28	.52	.54	.40	.32	.91	.72	.48
2019	.11	.10	.08	.08	.15	.38	.49	.47	.38	.92	.85	.62
2020	.03	.03	.02	.00	.05	.10	.41	.38	.39	1.0	.95	.90

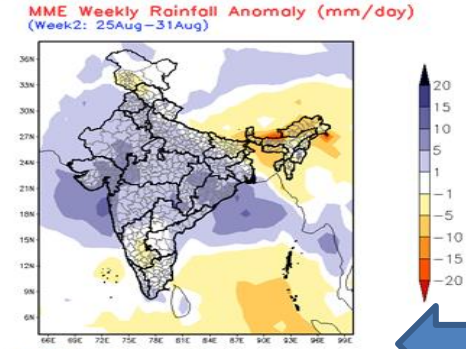
ERF for Hydrological applications

Heavy Rainfall Guidance for Flood, Reservoir Operation, Disaster Management

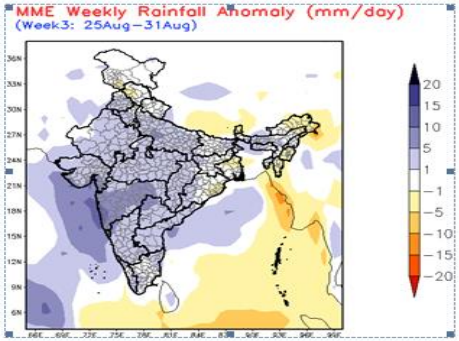
(a) IC – 23 Aug, 2017



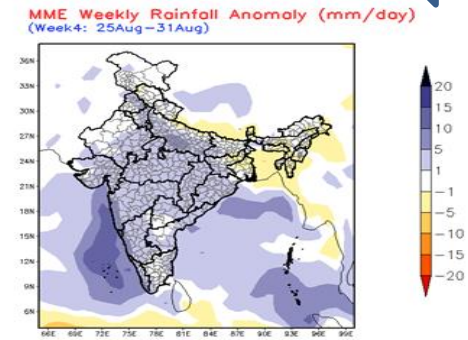
(b) IC – 16 Aug, 2017

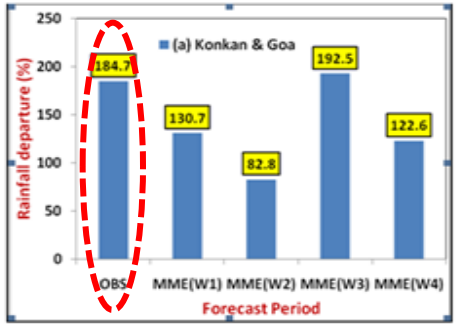


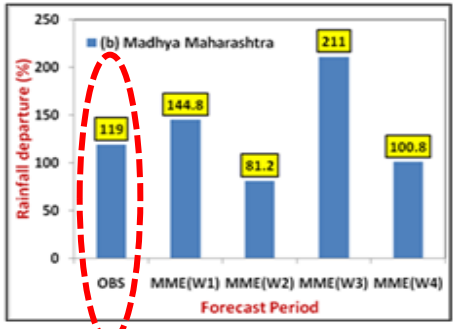
(c) IC – 09 Aug, 2017

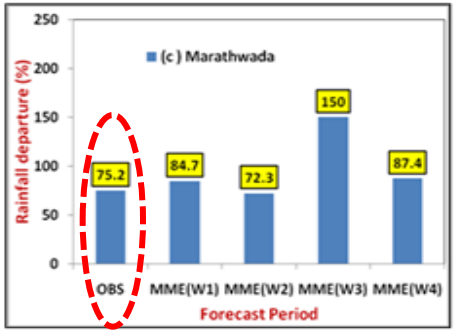


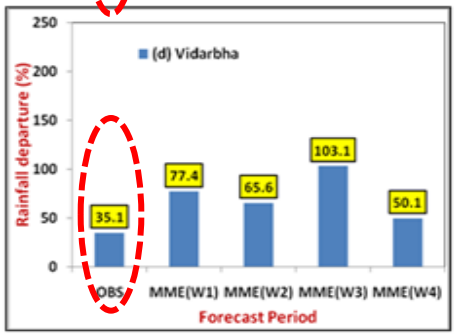
(d) IC – 02 Aug, 2017



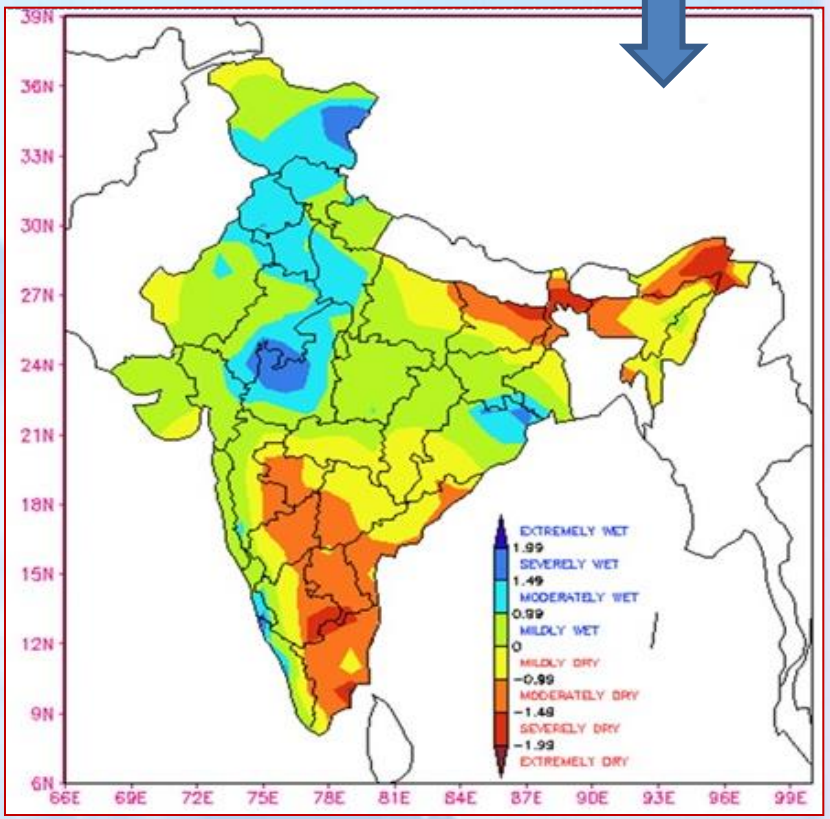








(25-31 August 2017); SPI

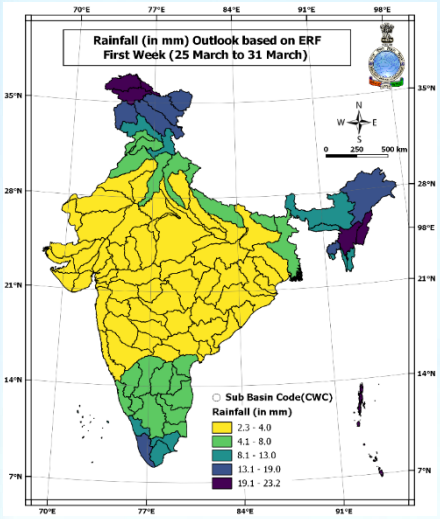


Standardized Precipitation Index (SPI) outlook based on the 4 weeks extended range forecast of 11 July, 2018 and valid for the period from 12 July to 8 August

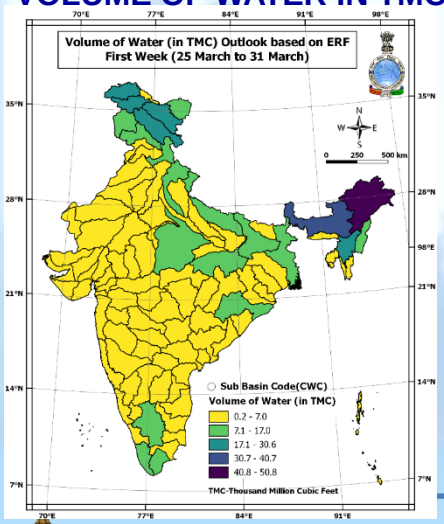
Hydrology: Weekly Rainfall Forecast for the 101 river sub basins of India based on ERF

WEEK 1

RAINFALL

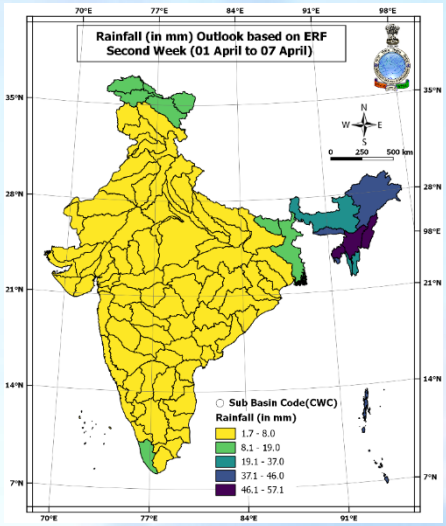


VOLUME OF WATER IN TMC



WEEK 2

RAINFALL



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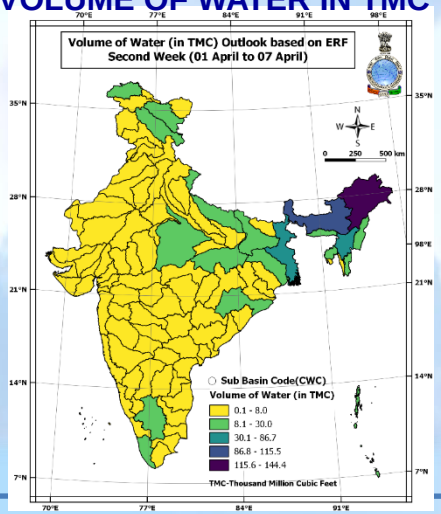
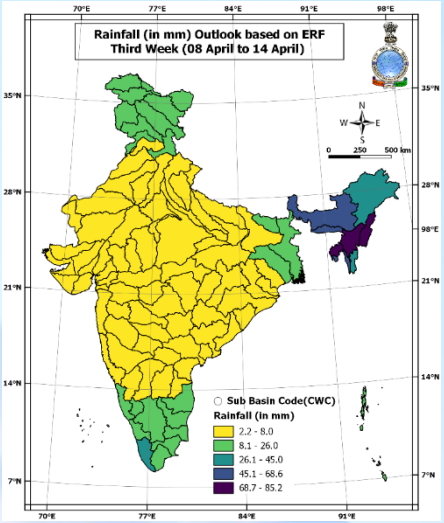
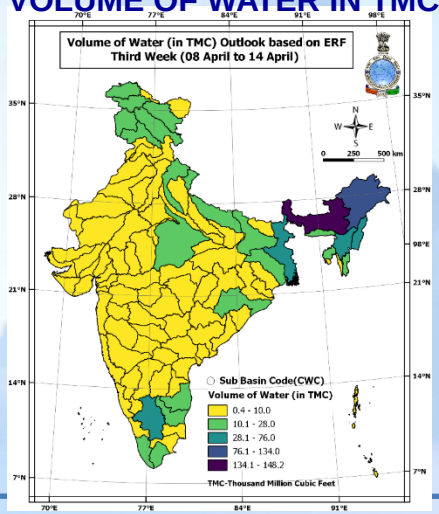


WEEK 3

RAINFALL

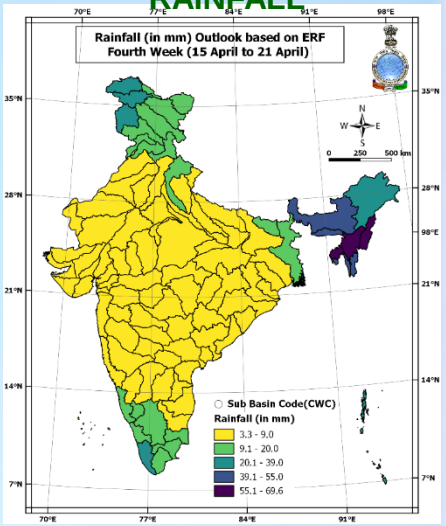


VOLUME OF WATER IN TMC

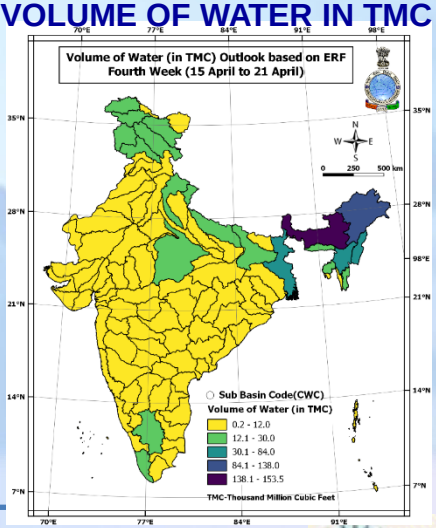


WEEK 4

RAINFALL



VOLUME OF WATER IN TMC



11-Apr-21

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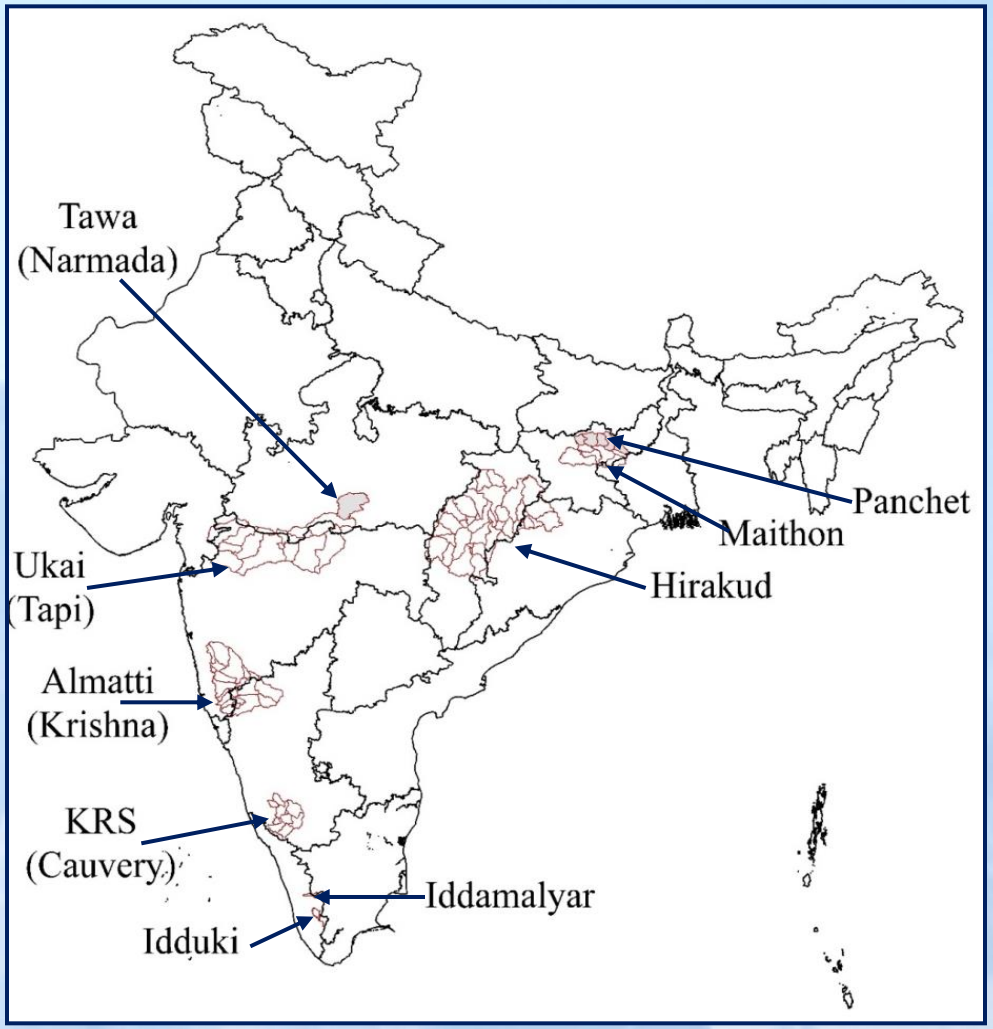
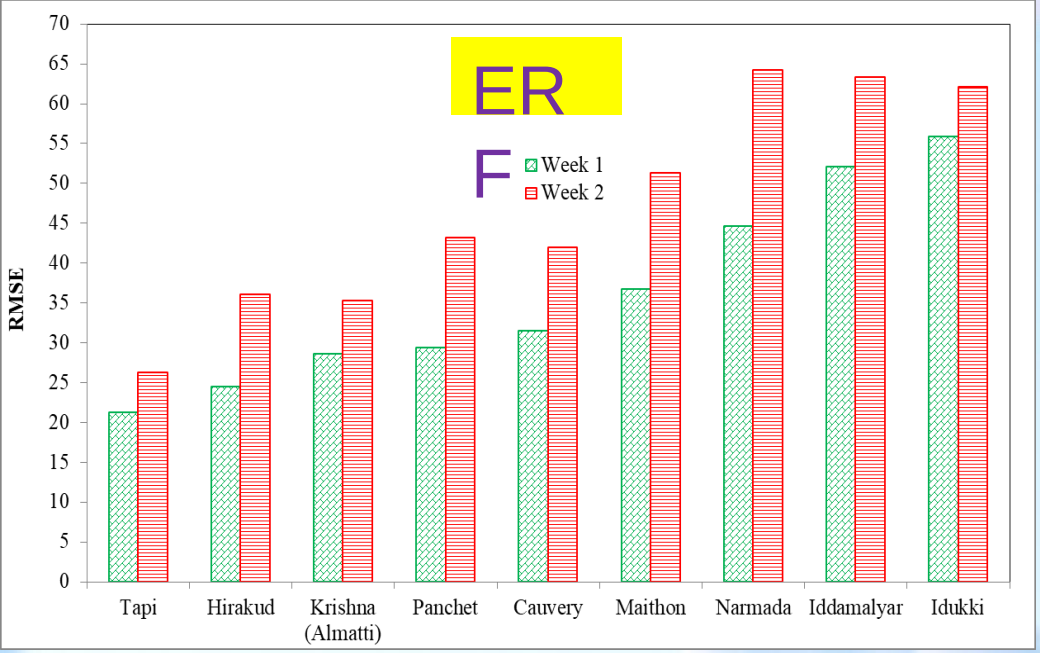
Map showing River basins

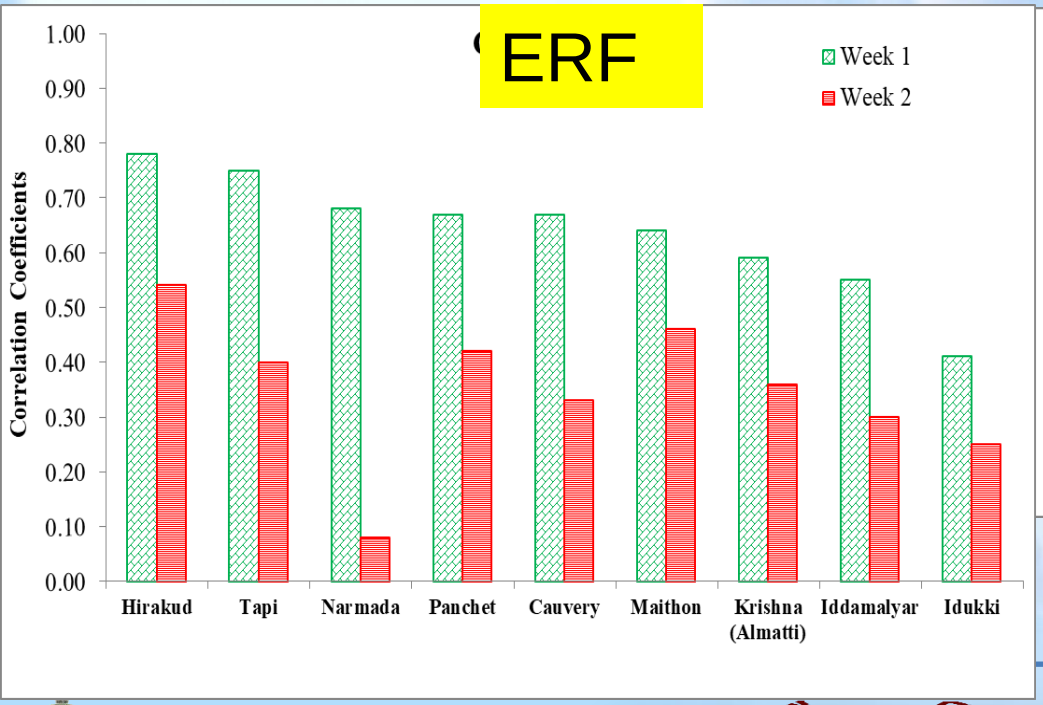
The nine river basins are:

1. Tawa (Narmada)
2. Ukai (Tapi)
3. Almatti (Krishna)
4. Krisna Raja Sagar (KRS)/ Cauvery
5. Idukki
6. Iddamalyar
7. Hirakud
8. Maithon
9. Panchet

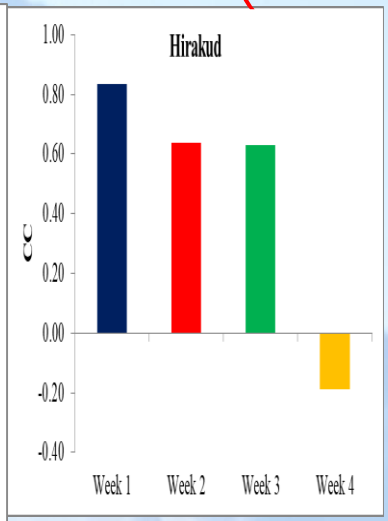


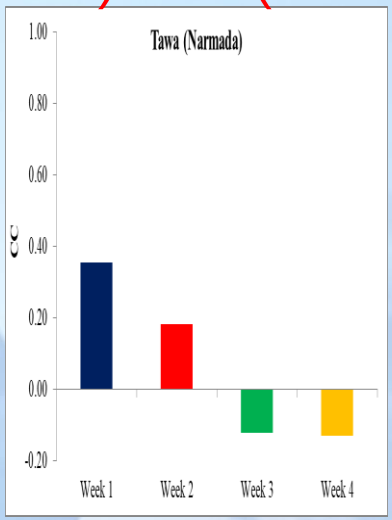


The highest Correlation Coefficients (CC) was found for the Hirakud river basin (Bigger Catchment) in the simulation of week 1, and followed by Tapi, Narmada, panchet, Cauvery, Maithon,Krishna, Iddamalyar, and Idukki respectively.



Hirakud (Mahanadi)Tawa (Narmada)





Lower skill at smaller catchment

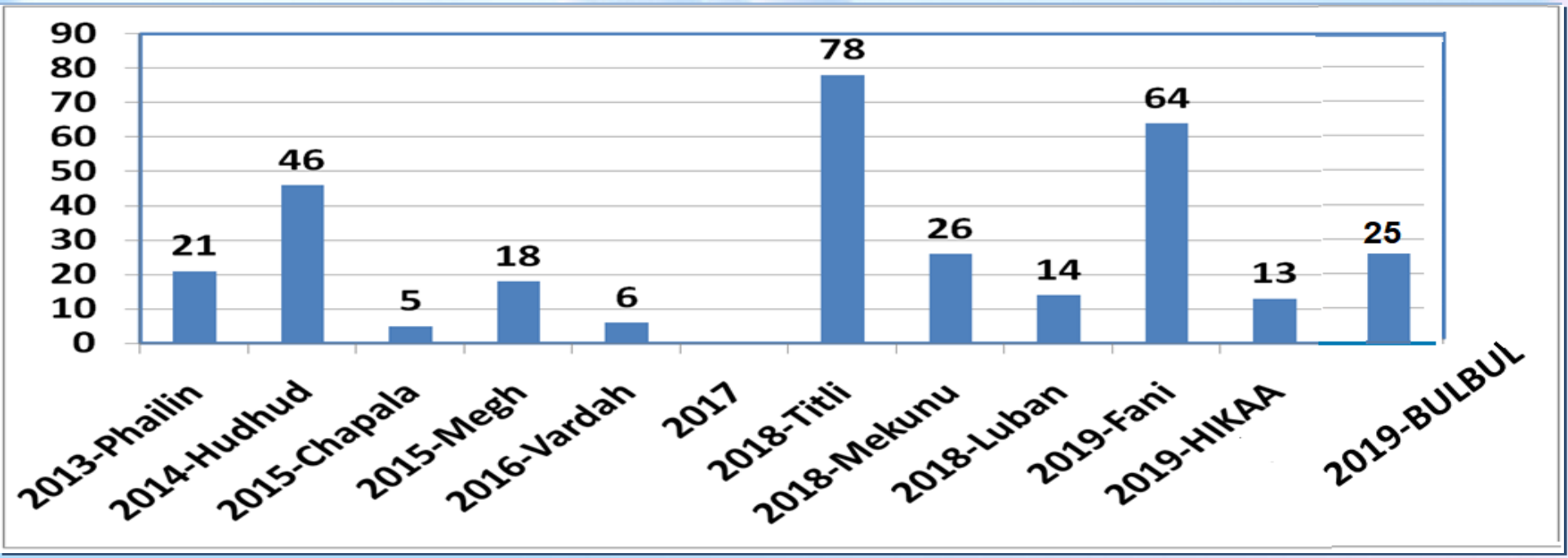
Flood/drought management and S2S Prediction

- Some centres are issuing probabilistic seasonal streamflow forecasts as part of climate outlook services, i.e. 3 month outlooks of total flow volumes rather than flood forecasts (e.g. Wood and Lettenmaier, 2006, in USA; Robertson and Wang, 2012, in Australia),
- S2S could be used to highlight increased chance of flooding where streamflow volume is predicted to be high for a season (White et al., 2015).
- Seasonal streamflow forecasts are contingent on climate information for short-term planning(e.g. water allocation) & setting up contingency.
- Water allocated based on seasonal forecasts issued at the beginning of the season requires revision using updated (i.e. subseasonal) forecasts throughout the season (Sankarasubramanian et al., 2009).
- S2S forecasting thus provides opportunity to integrate flood warning & streamflow forecasting communities for seamless hydrological forecasting service, extending flood forecasting to longer lead time through integration with rainfall runoff hydrological models (White et al., 2015) and improving water resource allocation & management decisions on S2S timescales

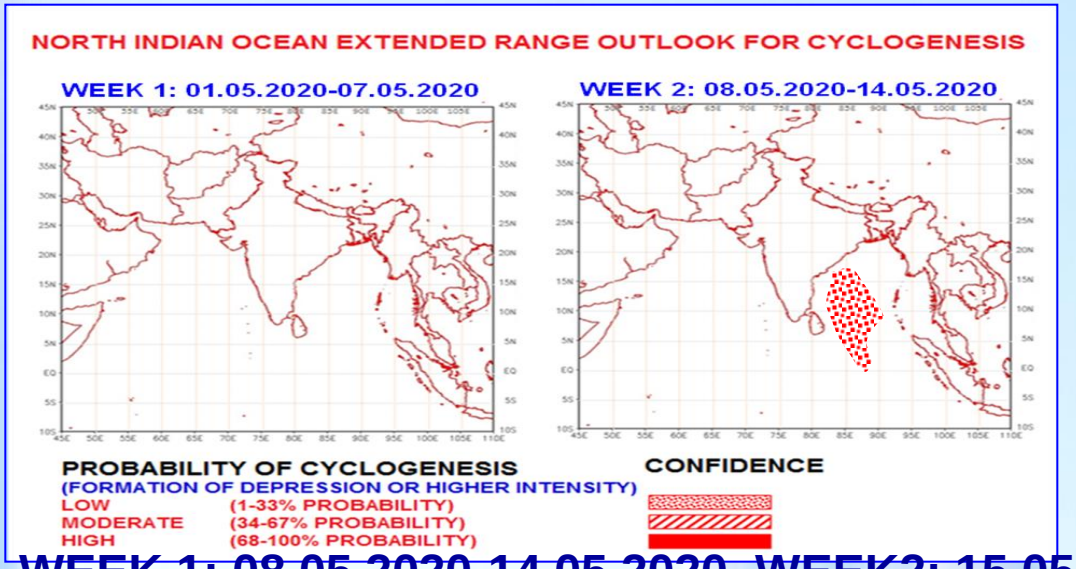
Death toll has reduced significantly in recent years

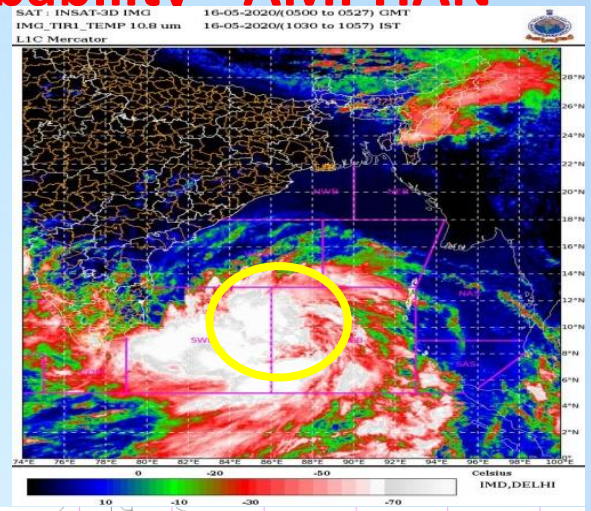
- Number of deaths less than 100 in recent years compared to thousands due to similar cyclones in past,
- For example. Odisha Super Cyclone in 1999 (10,000)
- It has been possible due to many proactive measures by central and state Governments and the improvement in early warning system

Loss Of Lives Due To Very Severe Cyclones (64 knots or more) crossing coast

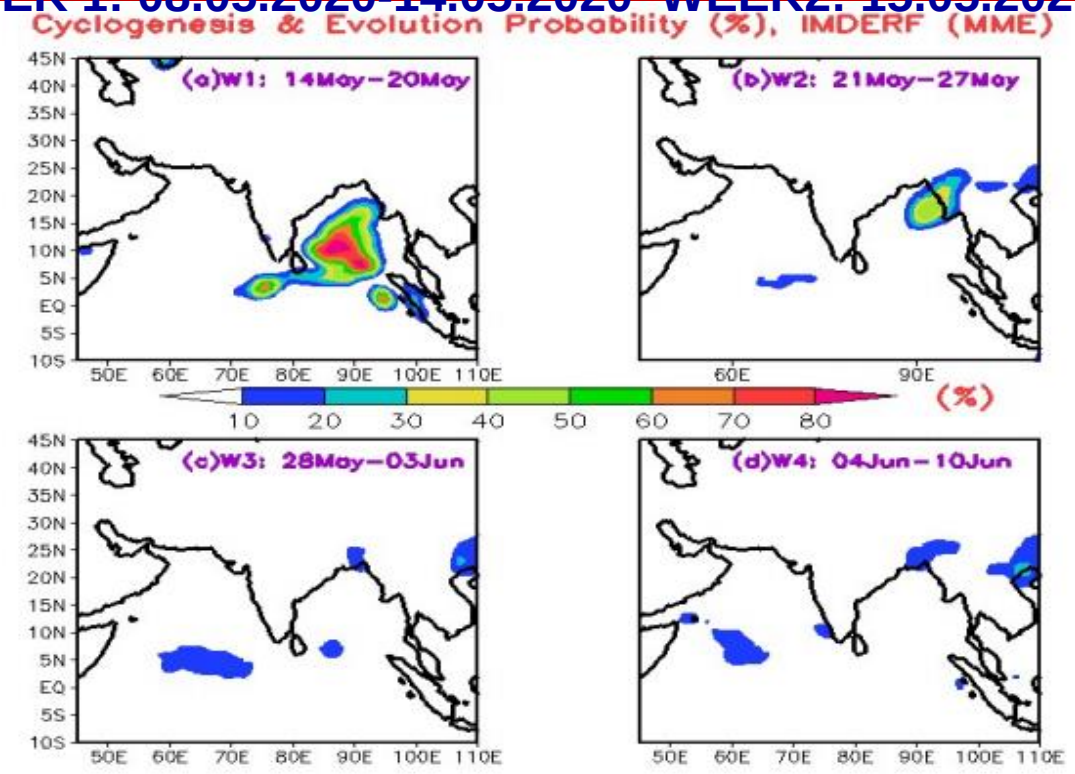


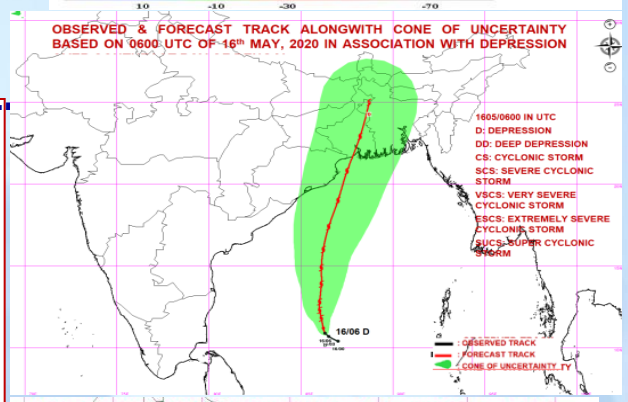
Extended Range Forecast of Cyclogenesis Probability "AMPHAN"

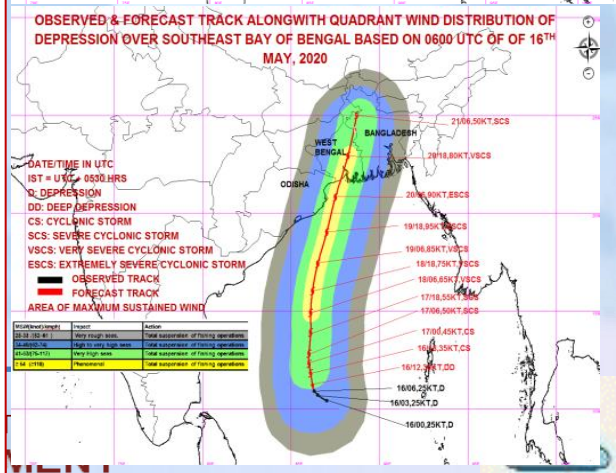




WEEK 1: 08.05.2020-14.05.2020 WEEK2: 15.05.2020-21.

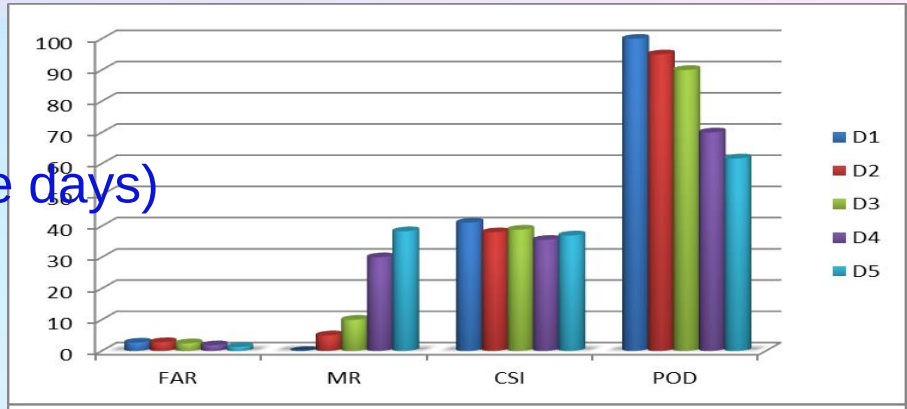




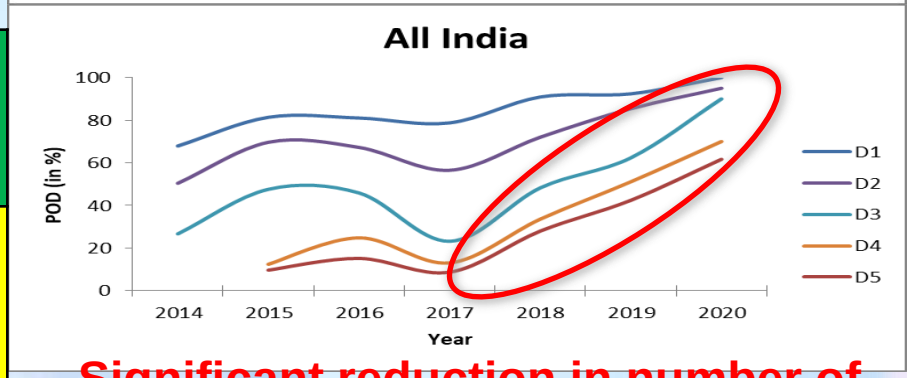


Heat Wave Warning Services

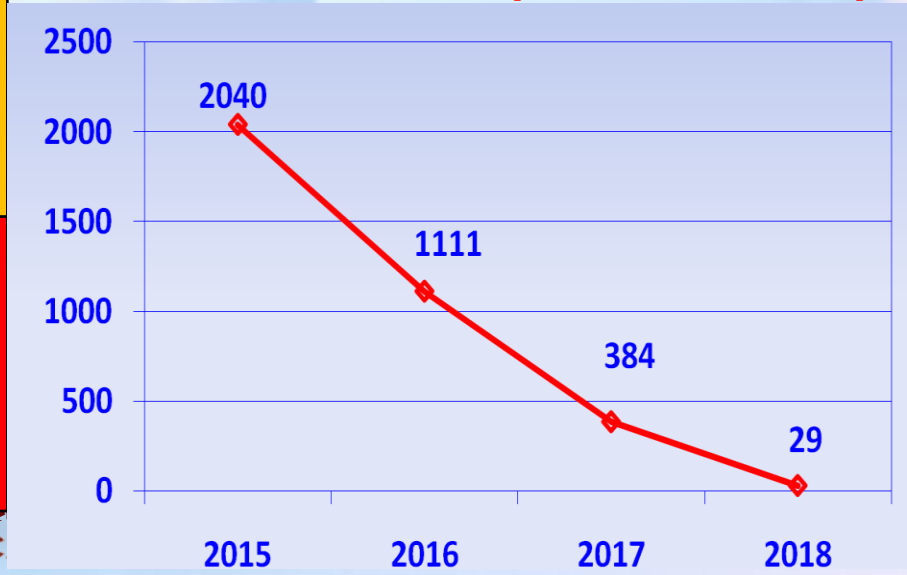
- Seasonal and extended range outlook
- District level heat wave warning (upto five days)
- Heat action plan with different states
- Heat action plan for cities



Green (No action)	Normal Day	Maximum temperatures are near normal
Yellow Alert (Be updated)	Heat Alert	Heat wave conditions at isolated pockets persists on 2 days
Orange Alert (Be prepared)	Severe Heat Alert for the day	(i) Severe heat wave conditions persists for 2 days (ii) Through not severe, but heat wave persists for 4 days or more
Red Alert (Take Action)	Extreme Heat Alert for the day	(i) Severe heat wave persists for more than 2 days. (ii) Total number of heat/severe heat wave days exceeding 6 days.

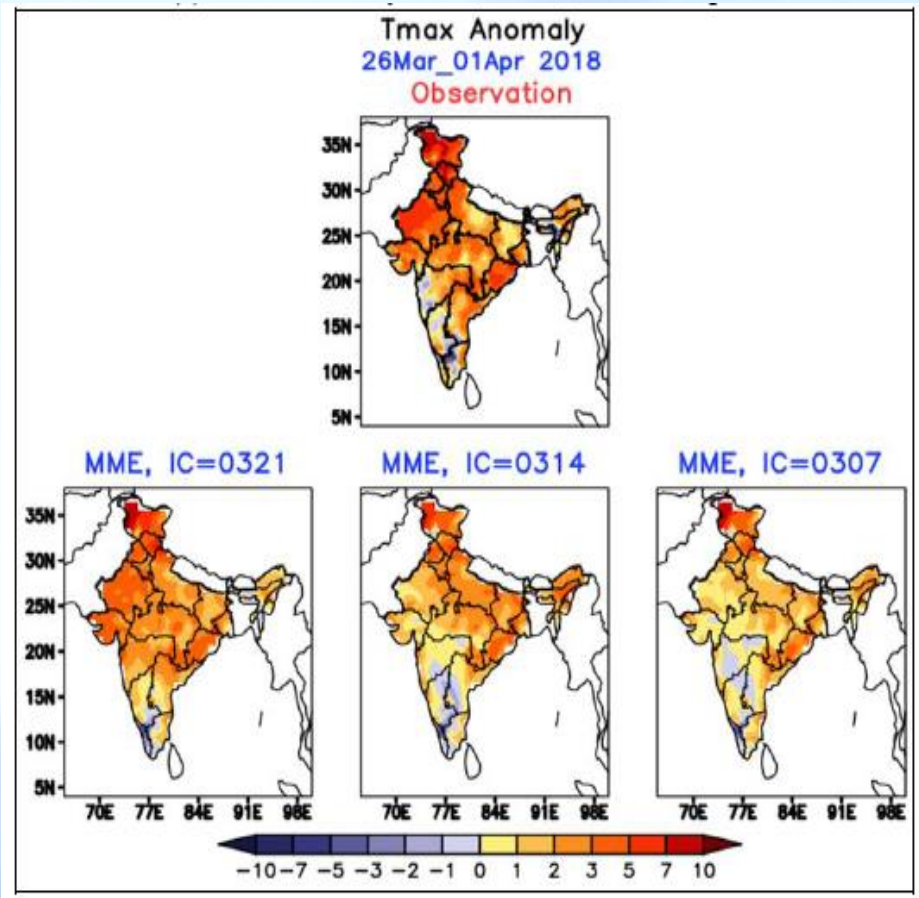


Significant reduction in number of deaths due to heat.(Source: NDMA)



S2S: Heat Wave Forecast

Tmax Anomaly
Target Week (26 March-01 April), 2019
ICs : 21 March, 14 March & 07 March



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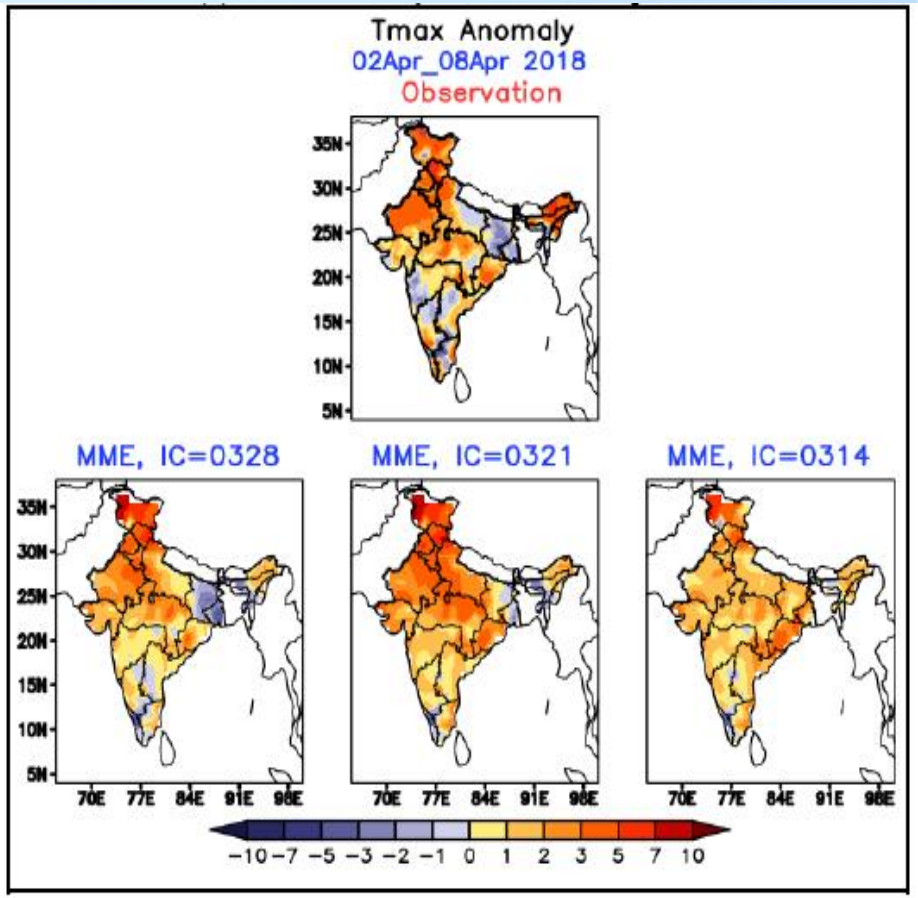
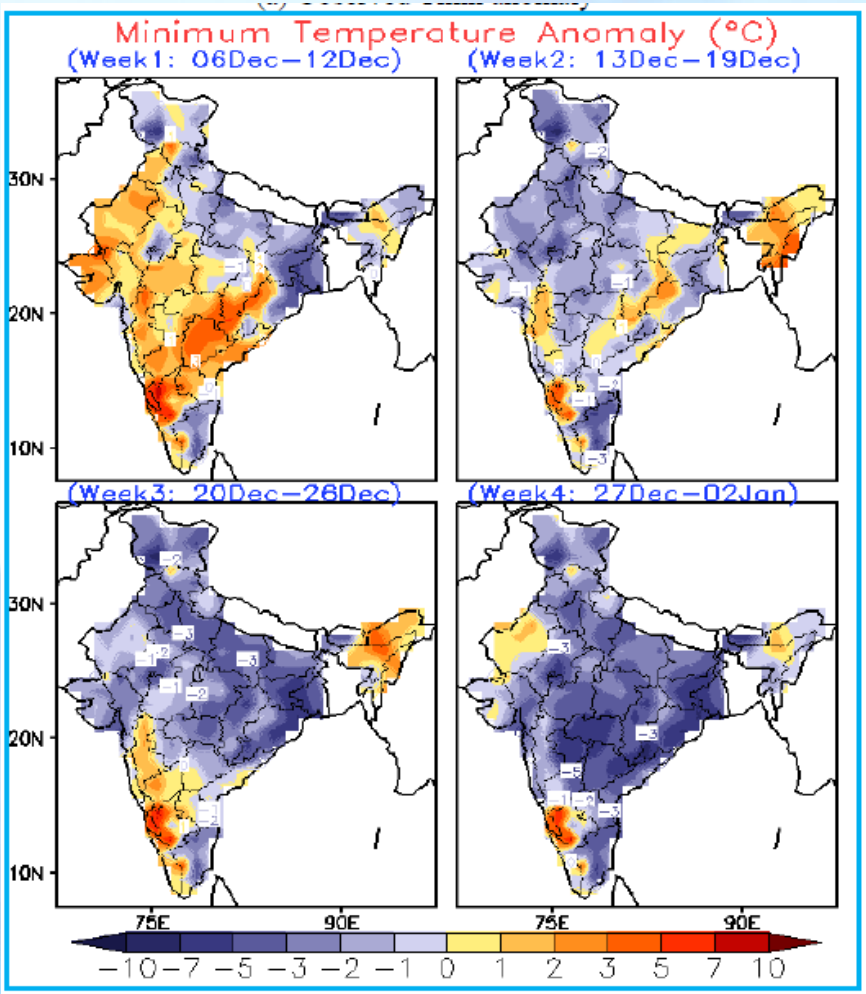
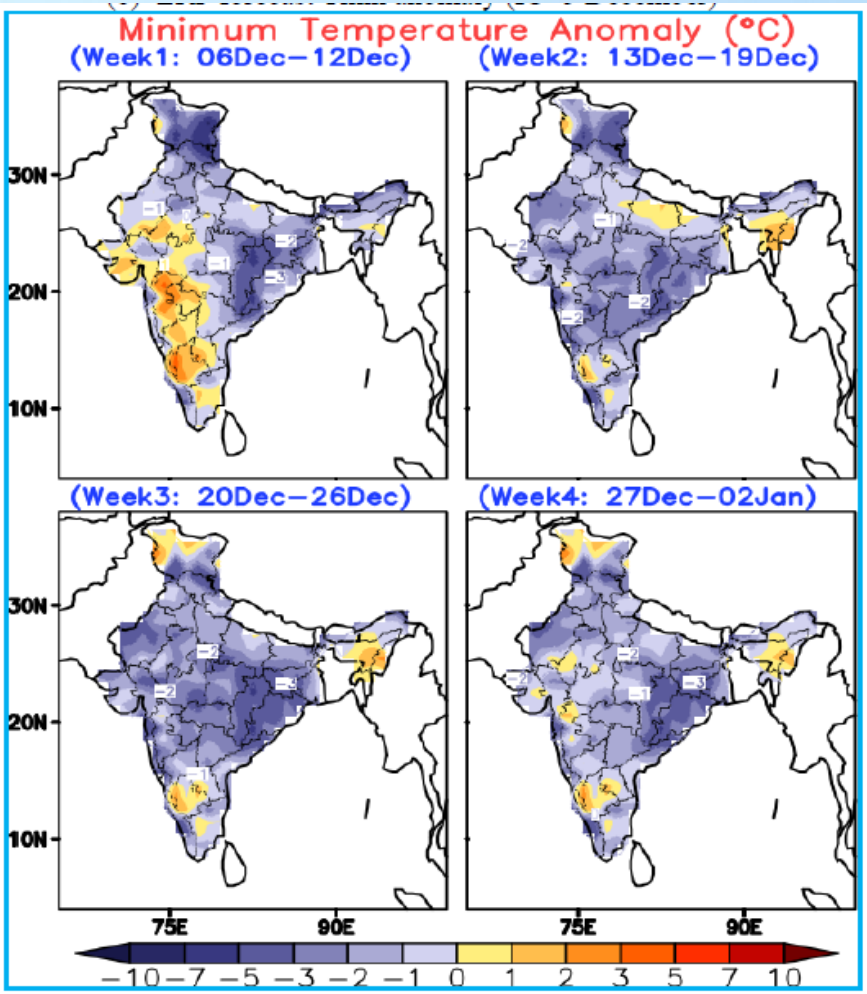


S2S: Cold Wave Forecast

Minimum Temperature Anomaly
06 Dec 2018 -02 Jan 2019

Extended Range Forecast for 4 weeks
Based on 5th Dec 2018





S2S Prediction for DRR: applications

- Undertake rapid assessments and continuous surveillance
- Hazard mitigation, e.g., release water from dams to prevent collapse, protect infrastructure with sandbags
- Activate institutional processes e.g., to support procurement, resource allocation, financial risk management, responsive social protection systems
- Activate existing contingency plans and coordination structures
- Alert volunteers & ensure availability of volunteers in affected areas
- Provide media distributors with instructions, so early warning announcements can be made rapidly
- Distribute instructions amongst public for accessing, understanding early warnings
- Ensure emergency supplies – confirm procurement chains, activate pre-identified service/commodity/cash providers, pre-deploy resources to areas.
- Prepare evacuation routes e.g., according to exact path of tropical cyclone and shelters (resources, staffing, security)
- Address specific vulnerabilities – organize checks on elderly people during a heatwave deploy special assistance to people with limited mobility
- Other sectoral applications like management of port and coastal activities

Strategy for promoting S2S products for disaster risk reduction

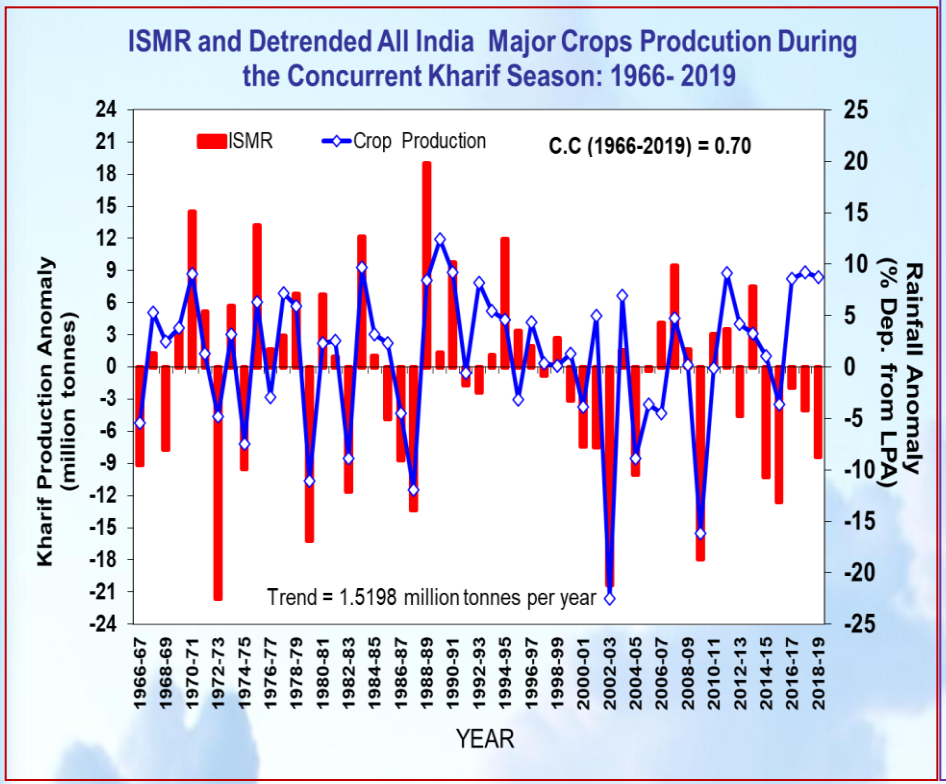
(United Nations Publication, ST/ESCAP/2867)

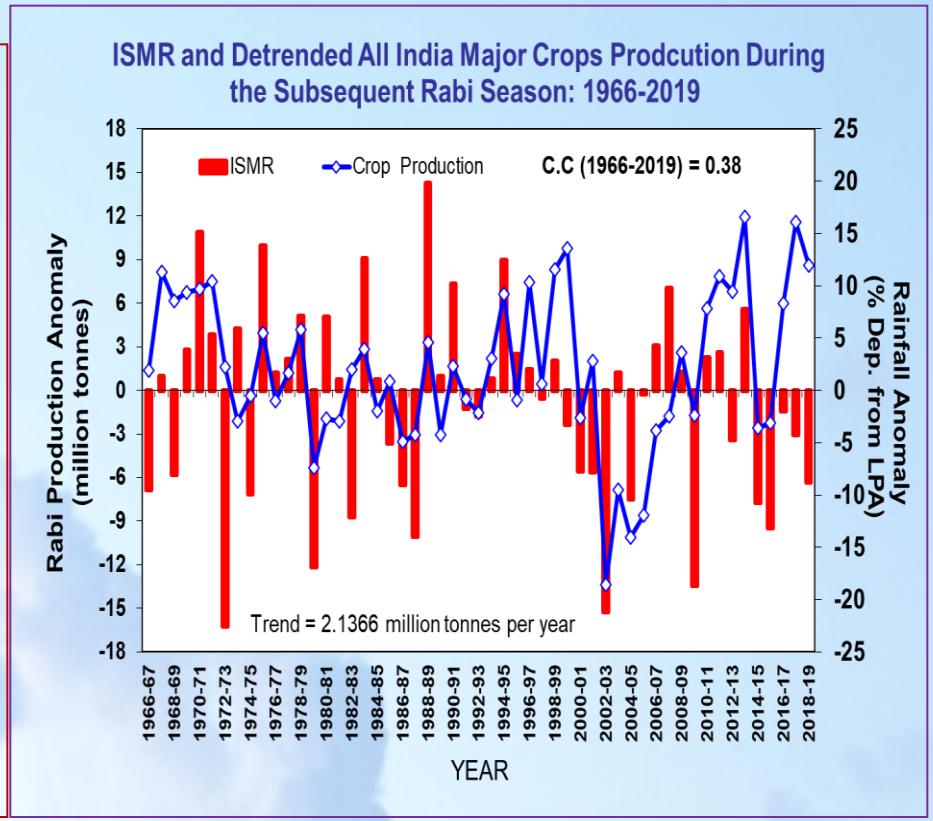
Source: Jiyul Shin, 2019.

Agriculture and S2S Prediction

- S2S timeframe is relevant for crop management, irrigation decisions, product marketing, input use (e.g. fertilizers) and commodity pricing.
- Using a similar approach to the Ready-Set-Go! concept, by extending downward from the seasonal scale, a seasonal forecast of rainfall totals might inform strategic decisions regarding crop-planting choices,
- S2S forecasts of rainfall extremes or heat waves could help irrigation scheduling and pesticide/fertilizer application (Vitart, 2014).
- S2S forecasts could be used as dynamic updates to an existing cropping calendar, such as for the estimation of crop yields (Vitart, 2014a) to help alleviate global food security issues (CGIAR, 2009).
- Regional mechanisms such as the strong intraseasonal oscillation, which is a major cause of monsoon breaks within the Indian monsoon season, could add valuable information for irrigation scheduling.

SW Monsoon Rainfall Vs Major Crops Production





- Crop production deviation for any year is a measure of the impact of the monsoon rainfall of that year.
- Above figures indicate strong positive correlation of all India summer monsoon rainfall with Kharif & Rabbi crop production

Indian Monsoon & Economics

Impact of a severe drought on GDP remains 2 to 5% throughout, despite the substantial decrease in the contribution of agriculture to GDP over the five decades (**Gadgil and Gadgil 2006**)

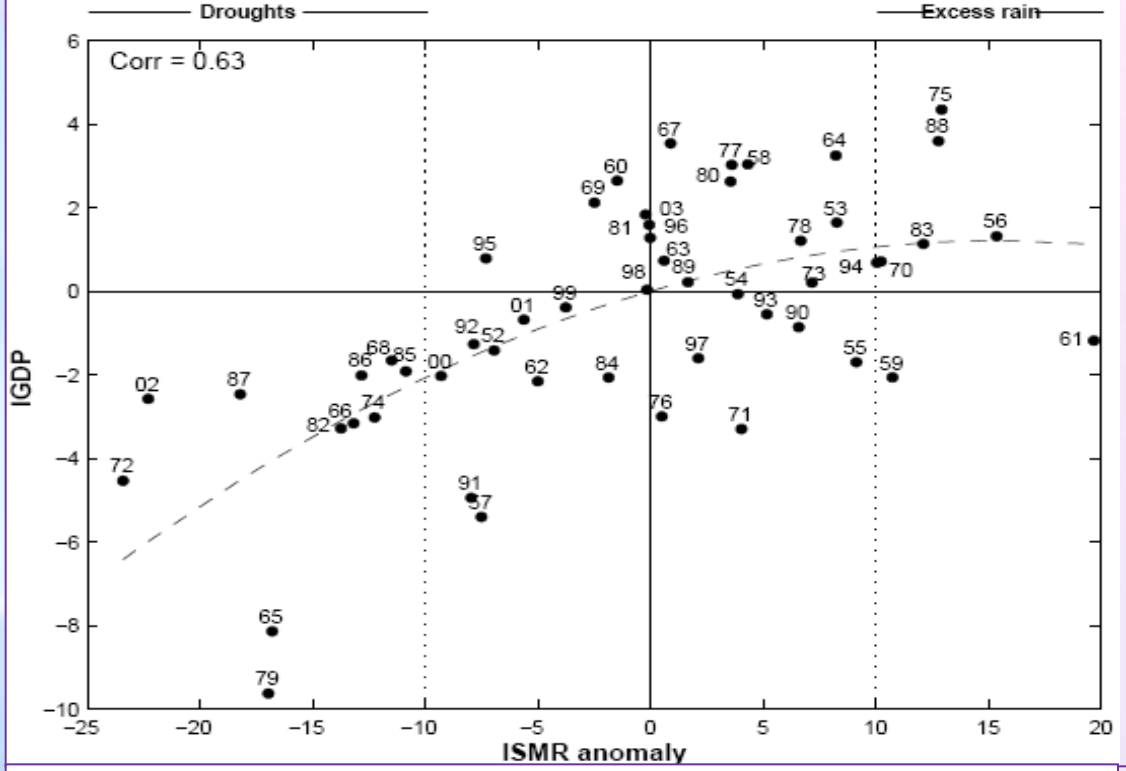
Labour force by occupation

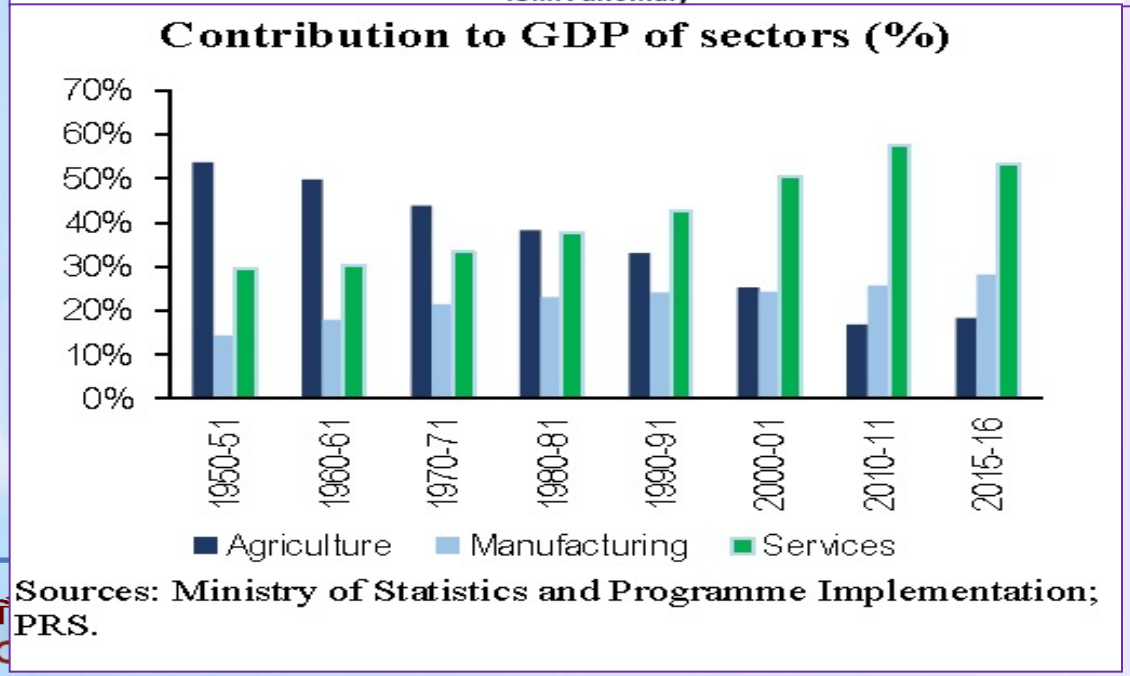
agriculture: 47%,

industry: 22%,

services: 31%

(2014 est.)





Sources: Ministry of Statistics and Programme Implementation; PRS.

Economic impact study of GKMS

Study conducted in year 2019 by National Centre for Applied Economic Research (NCAER), New Delhi. (The study interviewed 3,965 farmers across 121 districts of 11 states of India)

Salient findings-

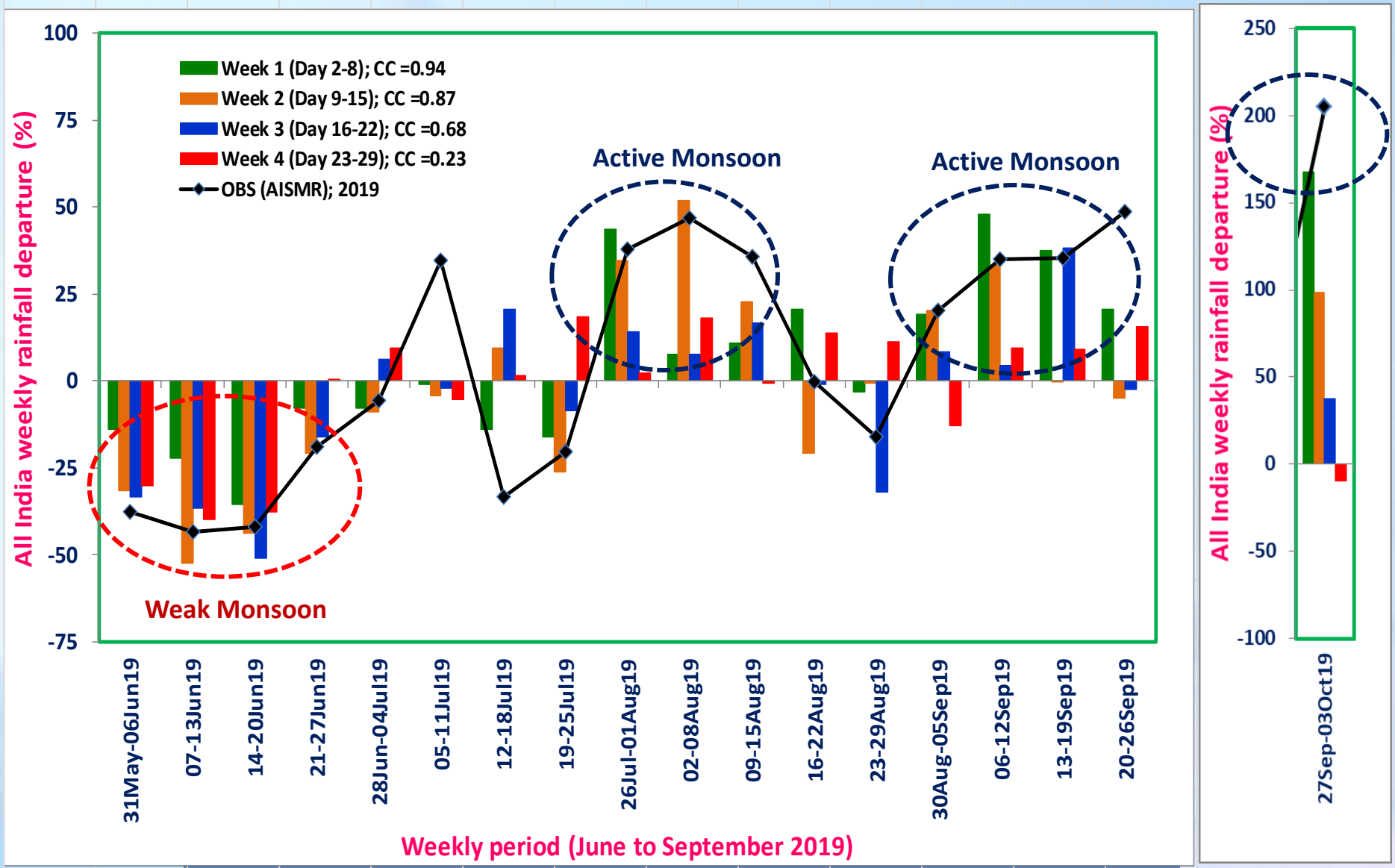
98% of surveyed farmers (~4000) made modifications to at least one of nine practices based on weather advisories

- Average Annual Income to the surveyed farmers

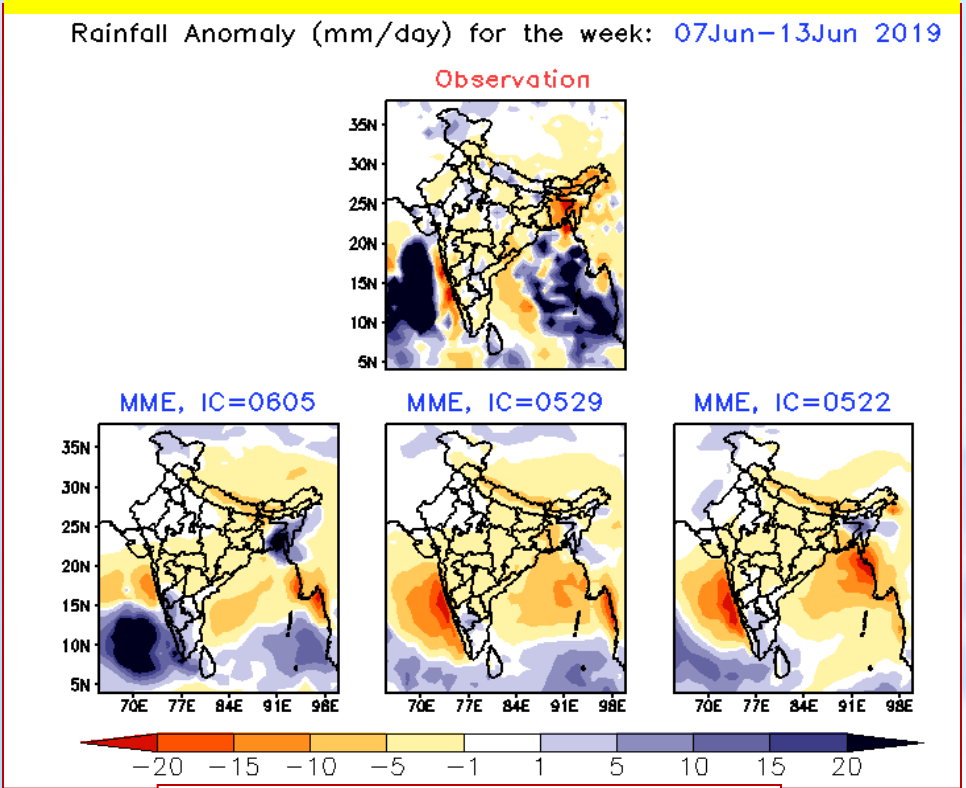
  Rs 2.43 Lakh with modification in 1 to 4 practices
  Rs 2.48 Lakh with modification in 5 to 8 practices
  Rs 3.02 Lakh in all the 9 practices
  Rs 1.98 Lakh with no modification [Control]

- 80% of farmers receiving information on high resolution weather events reported to have reduced losses.
- An estimated additional annual income of Rs. 12,500 per agricultural household belonging to Below Poverty Line category in rain-fed areas.
- Total income gain is estimated at Rs. 13,331 crore per annum in rain-fed districts.

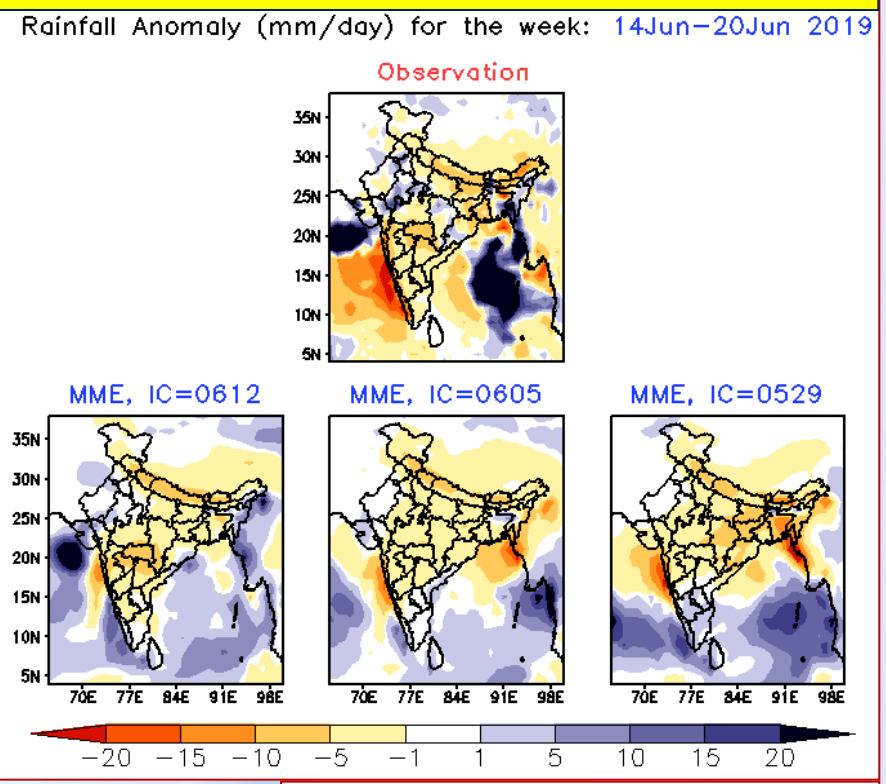
Anomaly CC – All India weekly rainfall, 2019 Monsoon

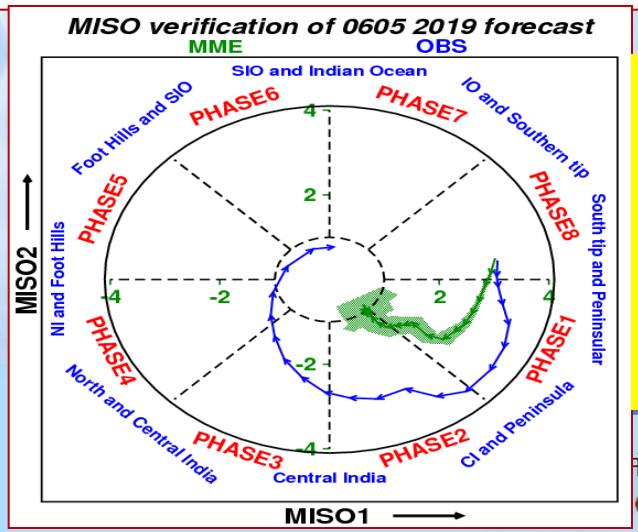


Target Week (07-13 Jun), 2019
ICs : 05 June, 29 May & 22 May



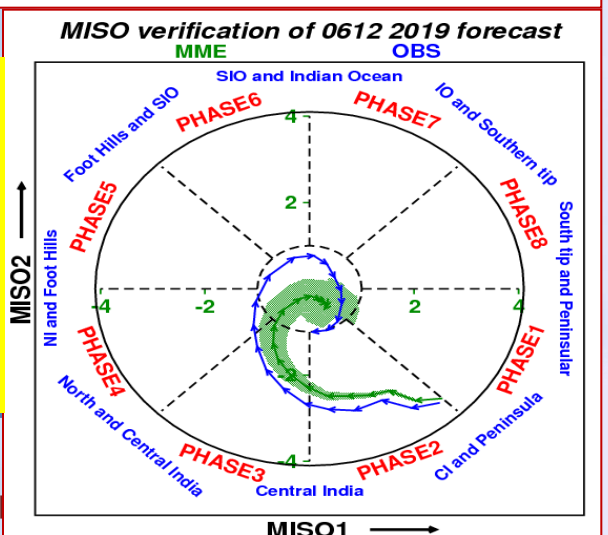
Target Week (14-20 Jun), 2019
ICs : 12 June, 05 June & 29 May





MISO Forecast

Weak Monsoon Conditions



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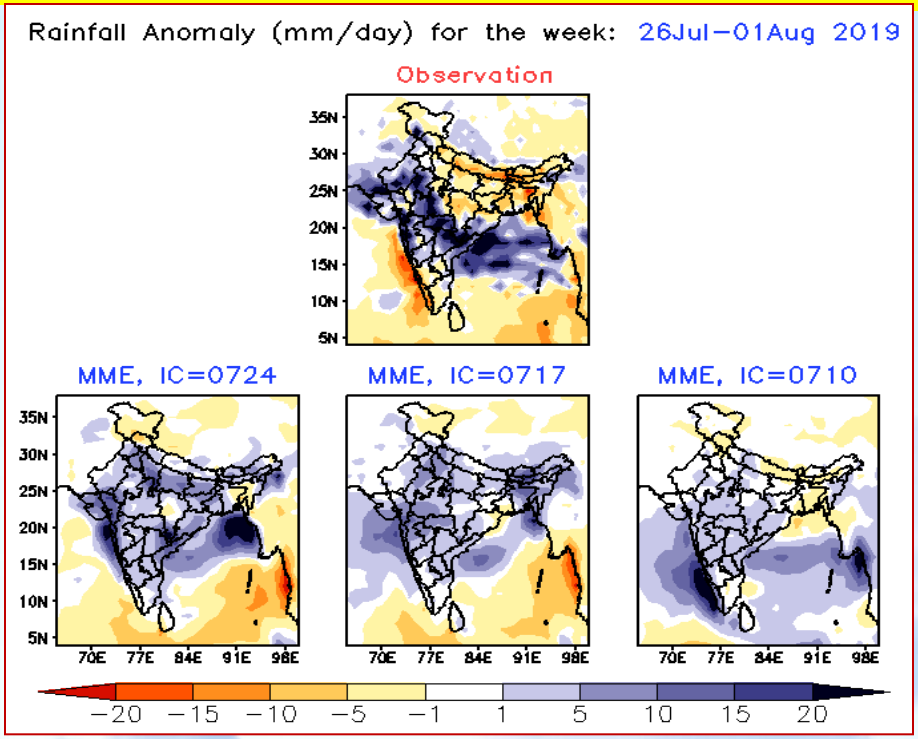
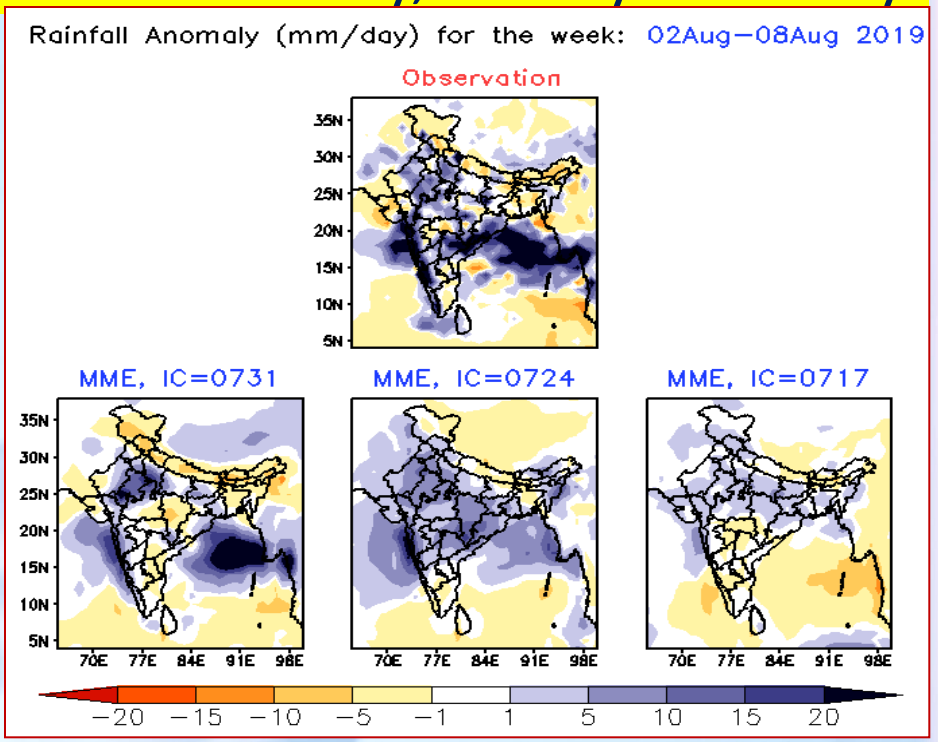
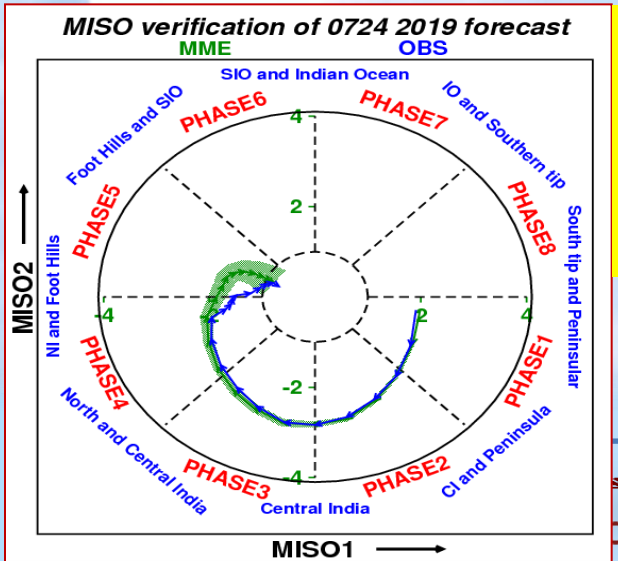
OROLOGICAL DEPARTM

Target Week (26 July-01 Aug), 2019
ICs : 24 July, 17 July & 10 July



Target Week (02-08 Aug), 2019
ICs : 31 July, 24 July & 17 July





MISO Forecast

Strong Monsoon Conditions

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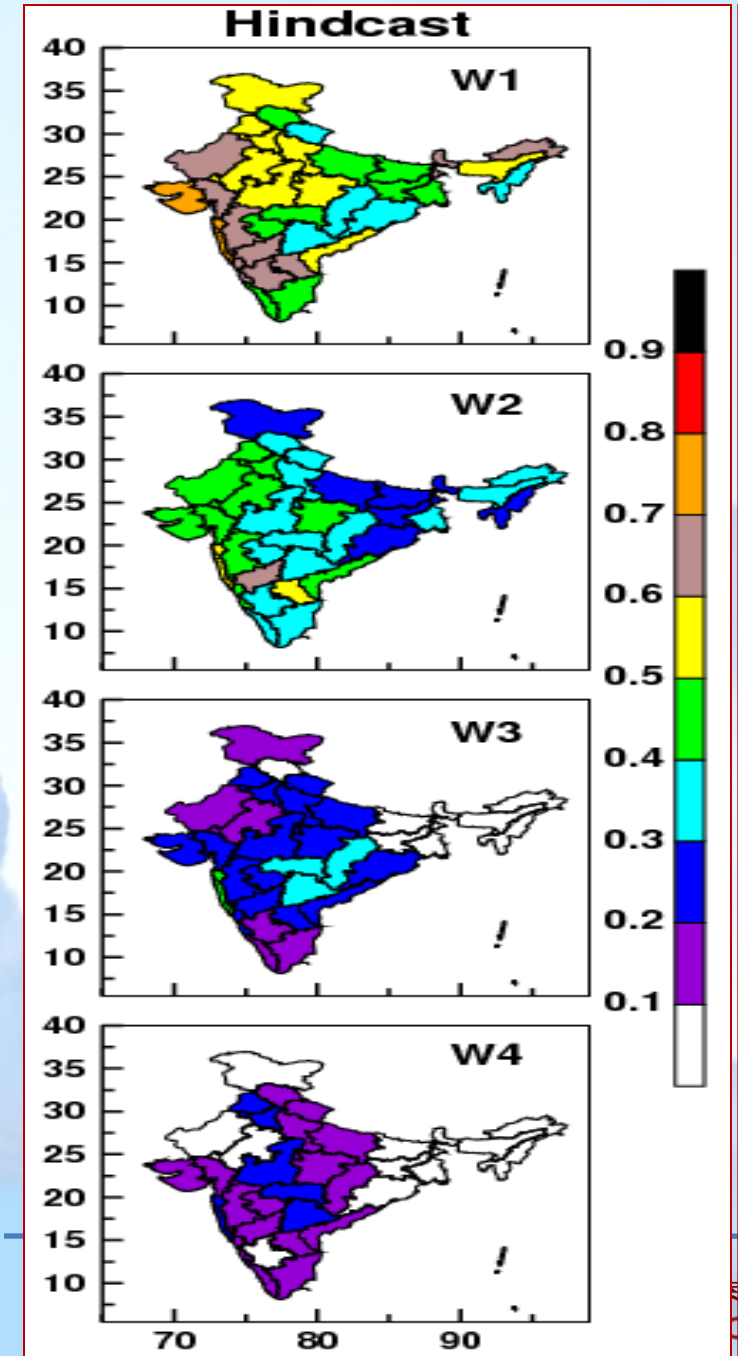
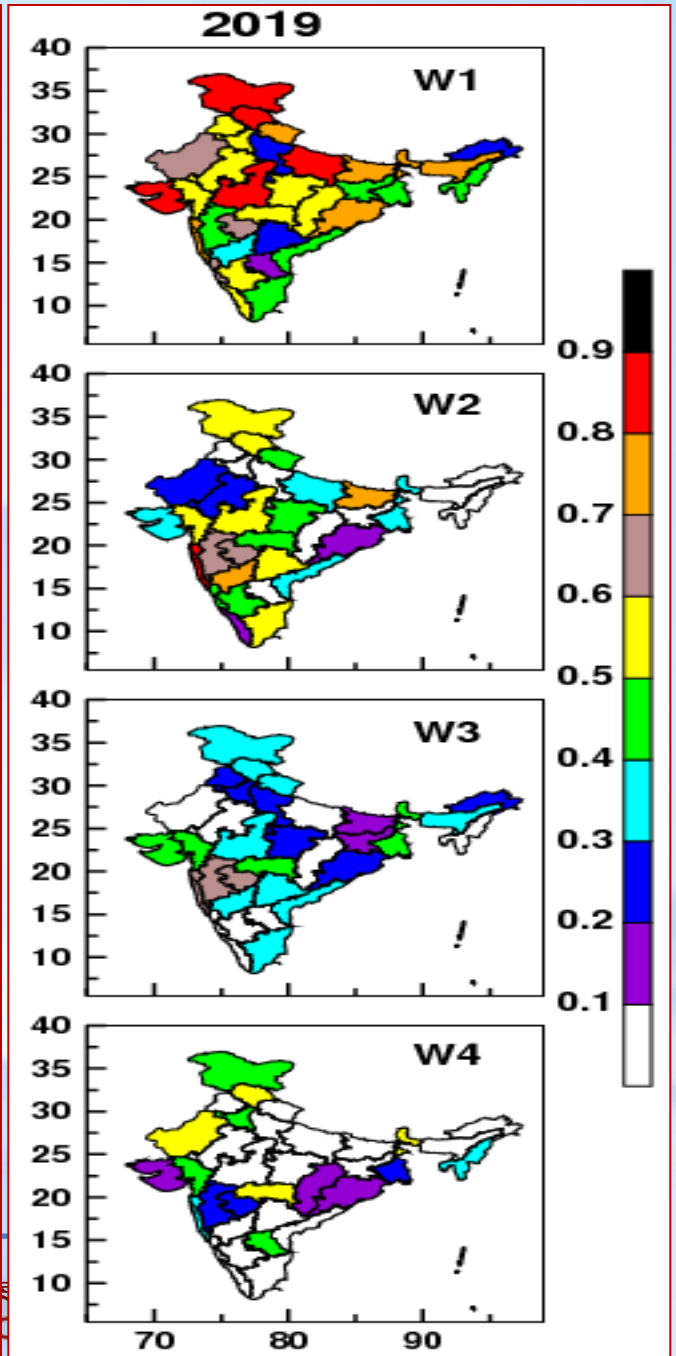
METEOROLOGICAL DEPARTMENT

Met Subdivision Scale Extended Range Hindcast & Forecast Skill

2003-2018



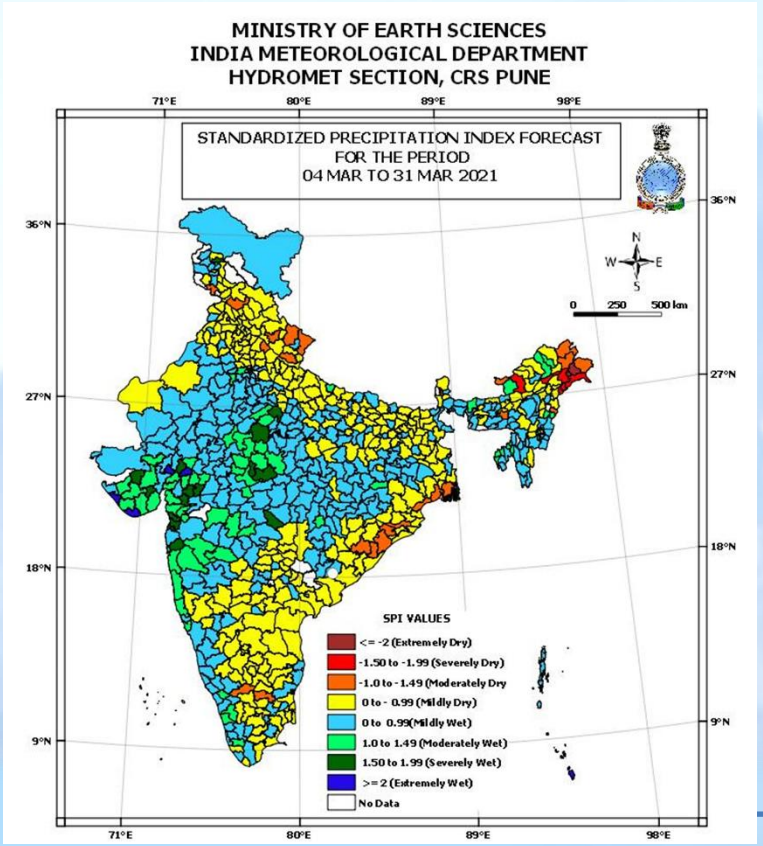


2019

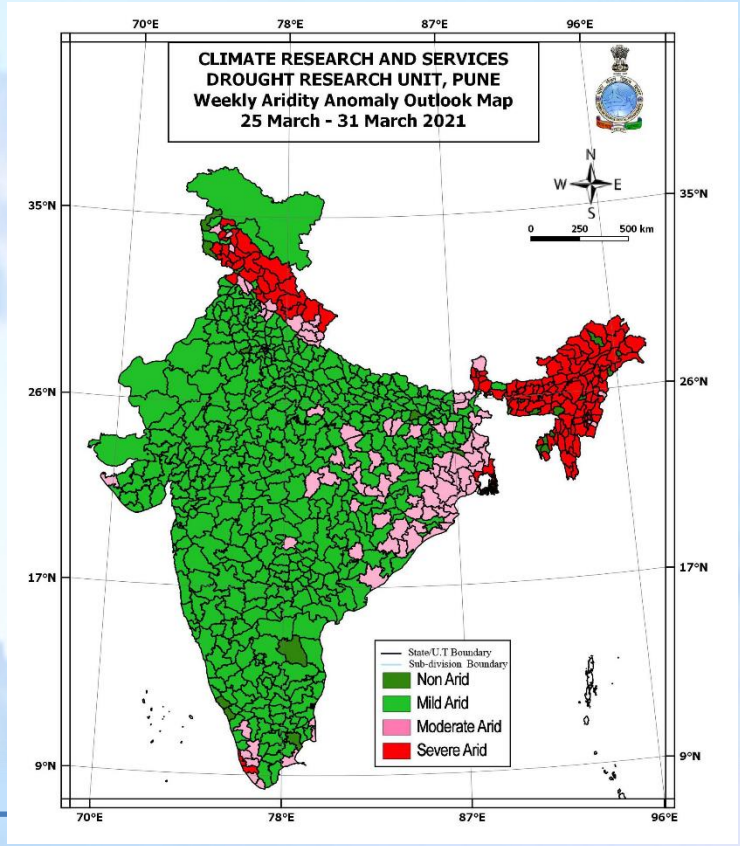
Agriculture : Drought outlook for National Agricultural Advisory

Based on GFS 1 week Rainfall Forecast

Dry/Wet Condition based on Standardized Precipitation Index for the districts at the end of 31st March issued on 25th March, 2021



Forecast Aridity Condition for the districts for the period 25 March to 31 March based on Aridity Anomaly Index issued on 25 March, 2021



भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Agriculture : Drought outlook for Agricultural Advisory

Based on ERF 2 - 4 weeks Rainfall Forecast

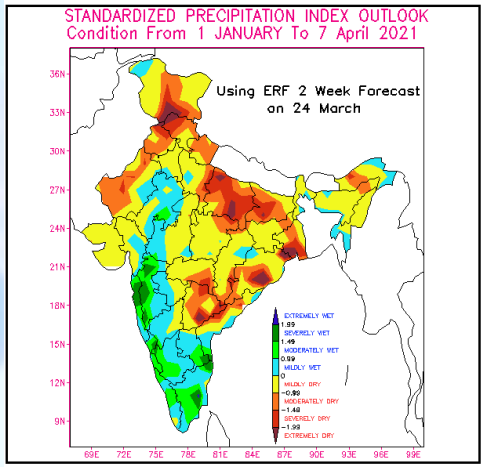
Dry/Wet Condition based on Standardized Precipitation Index for the districts at the end of coming 2 weeks, 3 weeks and 4 weeks since

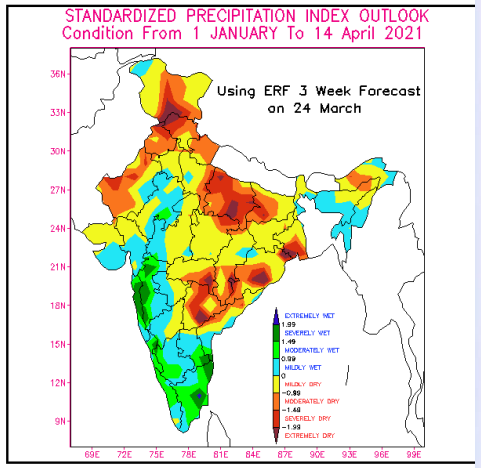
(a) 1st January, 2021 and

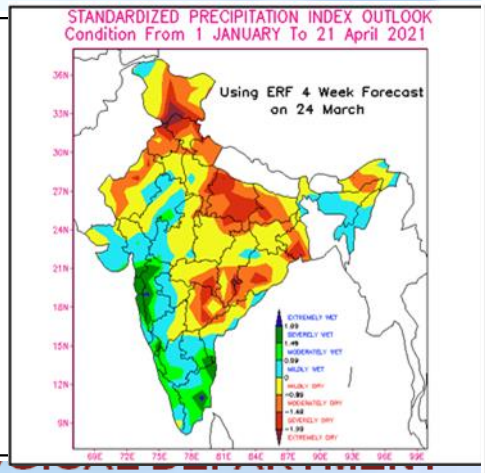
(b) 1st March, 2021

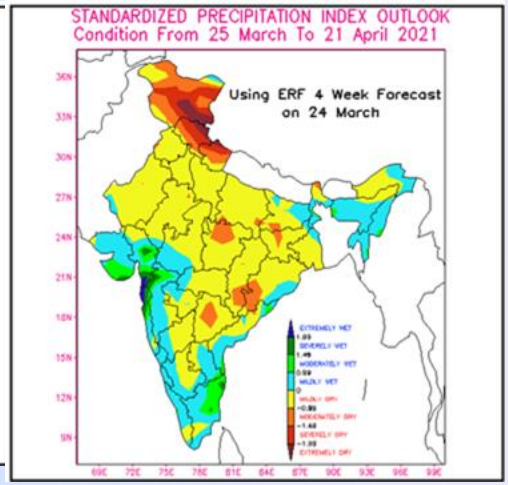
issued on 24 March

(a)

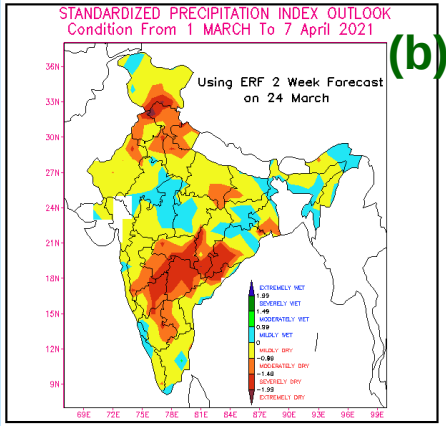


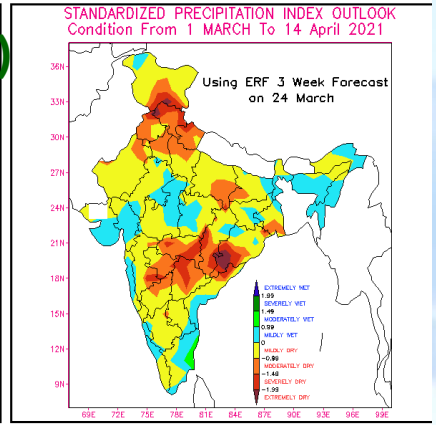


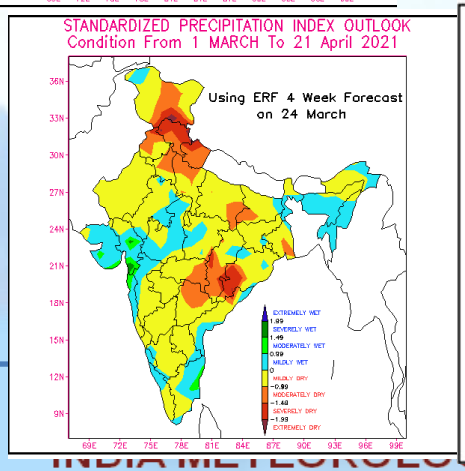




(b)







Weather forecasts 0-10 days	S2S predictions (2 weeks-2 months)	Seasonal predictions - over 3 months
• Issue early warnings to farmers • Evacuate livestock • Protect grains and seeds and equipment • Harvest crops earlier • Issue index-based insurance payouts to farmers	• Monitor agricultural output • Adjust planting, irrigation, pesticide, fertilizer and harvesting schedules • Support pastoralists - commercial destocking, vaccination, diagnosis and treatment of diseases, provide nutrition for core breeding animals • Provide materials and support for protection of livelihoods assets (e.g. through elevated platforms/safe spaces to keep food, livestock, seeds and tools) • Activate market systems to prevent food insecurity • Pre-position grain and seed protection bags • Provide cash transfers for fishing communities to safely store their nets, farmers to store farming equipment or to support evacuation of livestock e.g. ahead of an impending cyclone	• Select flood/drought resistant crop varieties / crop diversification • Plan use of pesticides and fertilizers, ploughing, tilling and irrigation scheduling to limit crop failure • Ensure access to agricultural risk insurance • Utilise nature-based solutions for protecting agricultural assets • Develop contingency plans for crop failures

Health Sector and S2S prediction

- S2S could be related to positive health outcomes, e.g.

❖ expected disease outbreak patterns, available medical supplies, poverty indicators).

- Heat/cold waves, for instance, are amongst the weather events that have the strongest societal impact with severe disruption of activities and significant loss of life.
- Prediction of the evolution of extreme event (including onset, persistence and decay) a few weeks in advance would be particularly useful.
- Case studies of subseasonal heat wave prediction are starting to demonstrate significant promise
- Issues around accuracy of forecasts, especially for predicting the timing, duration, location and severity of heat events, make heat wave forecasting complex and difficult to tailor to individual users' needs in S2S scale.

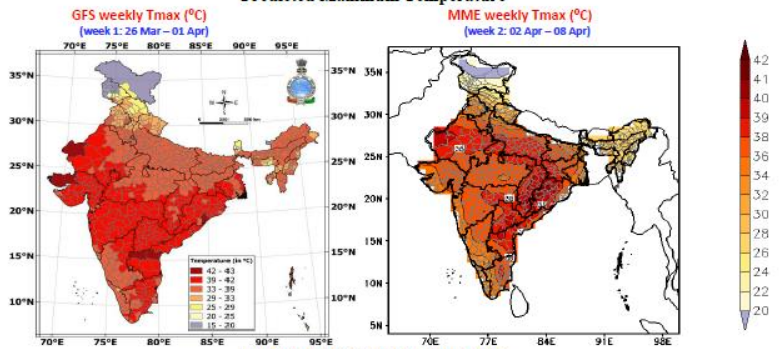
Weekly Climate Outlook for Health (Malaria and Dengue) Based on GFS and Extended Range Weather Forecast

Climate information for Health
Based on GFS and Extended Range Weather Forecast
(Valid from 26th March to 08th April, 2021)
Issued on 26th March, 2021
Office of Climate Research and Services, India Meteorological Department, Pune

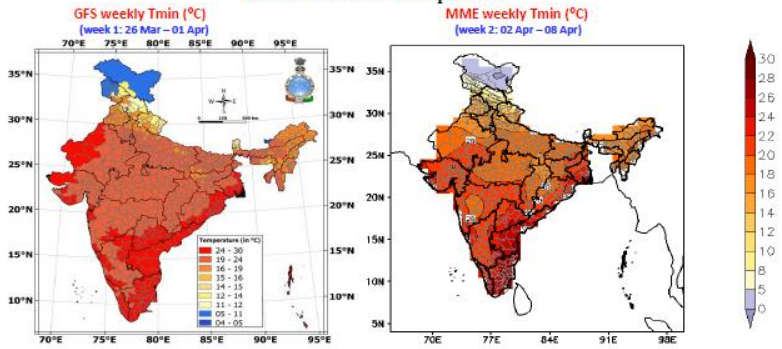
Climate information for coming two weeks is provided for the transmission windows of temperature favorable for development of vector borne diseases like malaria and dengue based on GFS and ERFS.

Weekly Prediction of maximum and minimum temperature

Predicted Maximum Temperature



Predicted Minimum Temperature



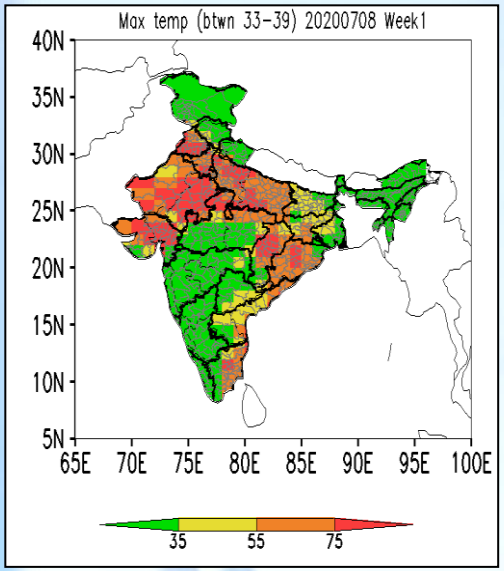
Weather Warning

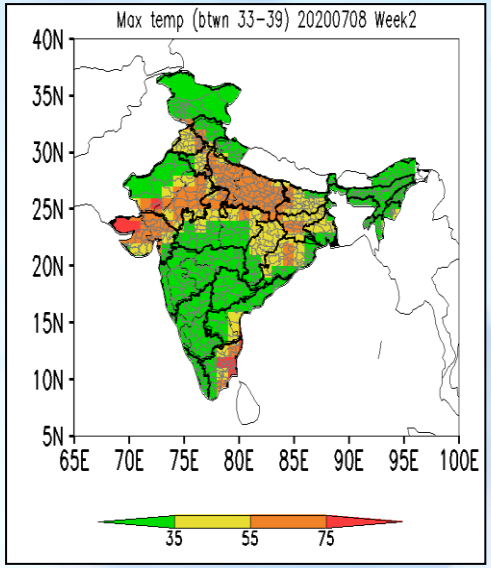
- Few districts of Rajasthan (Jaiselmer), Gujarat (Kachchh), Odisha (Ganjam), Andhra Pradesh (Kurnool, Prakashm) will experience maximum temperature above 42°C and Bandipur district of Jammu & Kashmir & Tawang districts of Arunachal Pradesh will experience minimum temperature below 5°C during 26th March to 01st April, 2021.

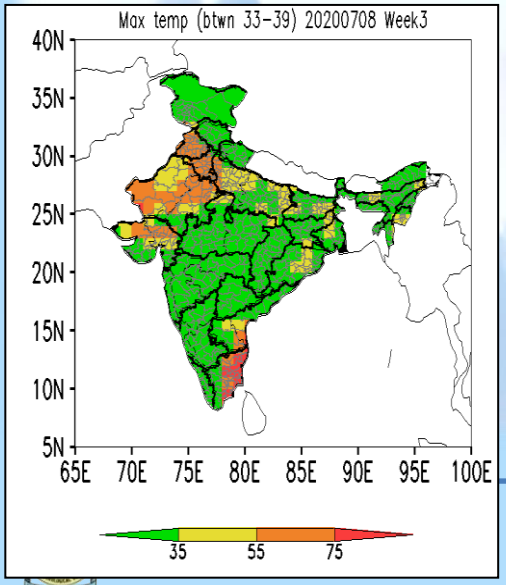
GFS based weekly evolution of transmission window for Malaria and Dengue for Week-I				
Week	VBD	Threshold temp.		Regions within the range of predicted temperatures for Tmax/Tmin or both in Threshold temperatures range.
		Th-Tmax	Th-Tmin	
26th Mar to 01st Apr 2021	Malaria (*Plasmodium falciparum*)	33-39°C	16-19°C	All districts of Bihar, Mizoram, Goa, Punjab (except Hoshiarpur, Pathankot, Firozpur), Uttar Pradesh (except Saharanpur, Prabudhnagar), Jharkhand (except Purbi & Paschim Singhbhoomi, saraikela), Arunachal Pradesh (except Anjaw, Tawang), Manipur (except Chandel, Ukhrul), Nagaland (except Kiphire), Kerala (except Kollam, Wayanad), major districts of Haryana, Madhya Pradesh, Karnataka, Assam, some districts of Rajasthan, Chhattisgarh, West Bengal, Meghalaya, Tripura, Tamil Nadu, few districts of Jammu & Kashmir (Jammu, Kathua, Samba), Himachal Pradesh (Chamba, Simla, Solan), Uttarakhand (Udham Singh Nagar, Pauri Garhwal), Gujarat (Dangs, Devbhoomi Dwarka, Valsad), Maharashtra (Mumbai, Sindhudurg) and Odisha (Deogarh, Jagtsinghpur, Gajapathi).
	Malaria (*Plasmodium Vivax*)	33-39°C	14-15°C	All districts of Bihar, Mizoram, Goa, Uttar Pradesh, (except Saharanpur, Prabudhnagar), Jharkhand (except Purbi & Paschim Singhbhoomi, saraikela), Arunachal Pradesh (except Anjaw, Tawang), Nagaland (except Saiha, Kiphire), Kerala (except Kollam, Wayanad), major districts of Haryana, Madhya Pradesh, Karnataka, Assam, some districts of Punjab, Uttarakhand, Rajasthan, Chhattisgarh, West Bengal, Meghalaya, Manipur, Tripura, Tamil Nadu, few districts of Jammu & Kashmir (Jammu), Himachal Pradesh (Una, Kangra), Gujarat (Dangs, Devbhoomi Dwarka, Valsad), Maharashtra (Mumbai, Sindhudurg), Sikkim (North Sikkim) and Odisha (Deogarh, Jagtsinghpur, Gajapathi).
	Dengue	Not known	11.9°C	Few districts of Himachal Pradesh (Kullu, Lahul & Spiti).
ERFS based weekly evolution of transmission window for Malaria and Dengue for Week-II				
02nd to 08th Apr 2021	Malaria (*Plasmodium falciparum*)	33-39°C	16-19°C	Haryana, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Goa, Kerala, Tamil Nadu, major parts of Punjab, Rajasthan, Bihar, Chhattisgarh, Jharkhand, West Bengal, North-eastern states, Telangana, Andhra Pradesh, some parts of Uttarakhand and Odisha.
	Malaria (*Plasmodium Vivax*)	33-39°C	14-15°C	Haryana, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Goa, Kerala, Tamil Nadu, major parts of Punjab, Rajasthan, Bihar, Jharkhand, West Bengal, Telangana, Andhra Pradesh, some parts of Uttarakhand Chhattisgarh and Odisha.
	Dengue	Not known	11.9°C	Some parts of Himachal Pradesh, isolated parts of Jammu & Kashmir and Uttarakhand.

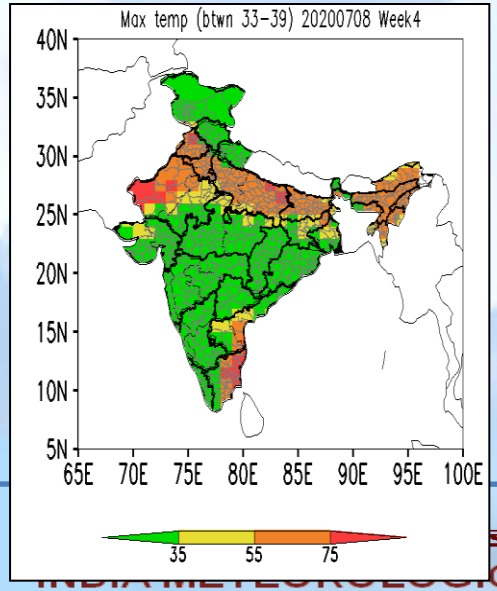
Probabilistic prevalence of transmission window for Malaria Tmax (33-39 C) and Tmin (16-19 C); IC 8th July 2020

Tmax (33-39 C)

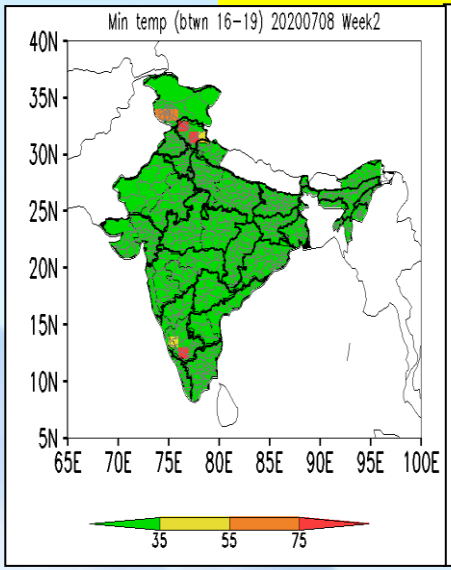


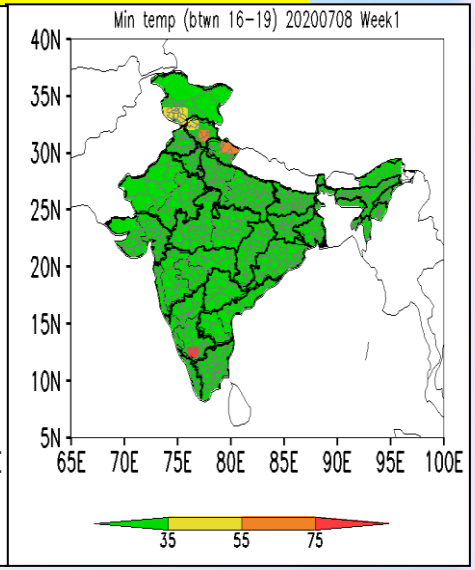


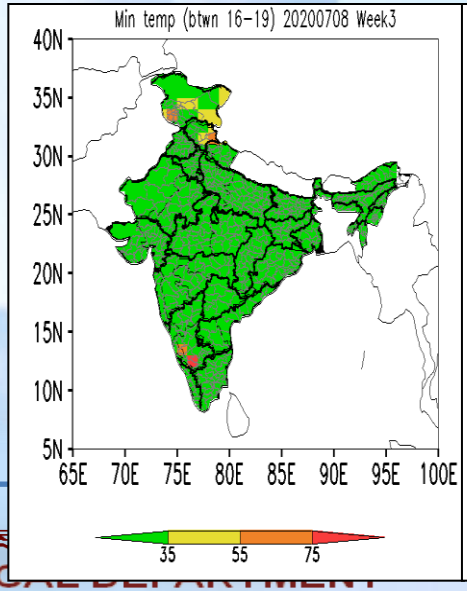


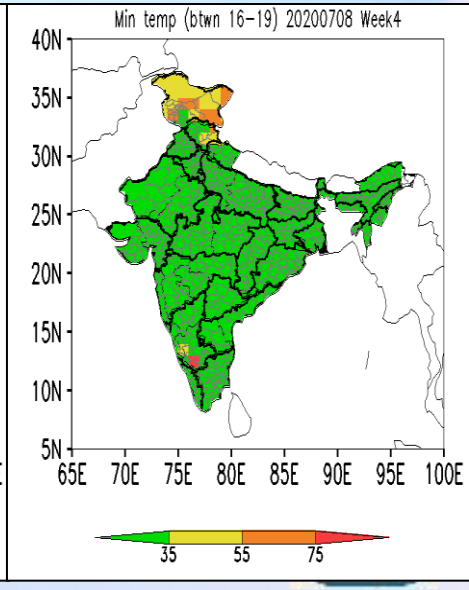


Tmin (16-19 C)









Health Sector and S2S prediction: Applications

Heat/cold wave related:

- ❖ alerting decision makers and the general public to impending dangerous hot weather,
- ❖ advise individuals on how to avoid excessive heat exposure,
- ❖ spread awareness of symptoms of heat-related illnesses
- ❖ Preposition medical supplies
- ❖ Organize staffing of health centres
- ❖ Prepare cooling centres

- Water related:
- Stock materials such as pesticides for mosquito fumigation, chlorine tablets for water purification non-food items to improve hygiene and water storage
- Public information campaigns and community mobilization
- Train community volunteers and hygiene motivators
- Provide safe water and sanitation to shelters
- Provide raised latrines and drainage in flood-prone areas
- Revise water allocations and activate water conservation practices

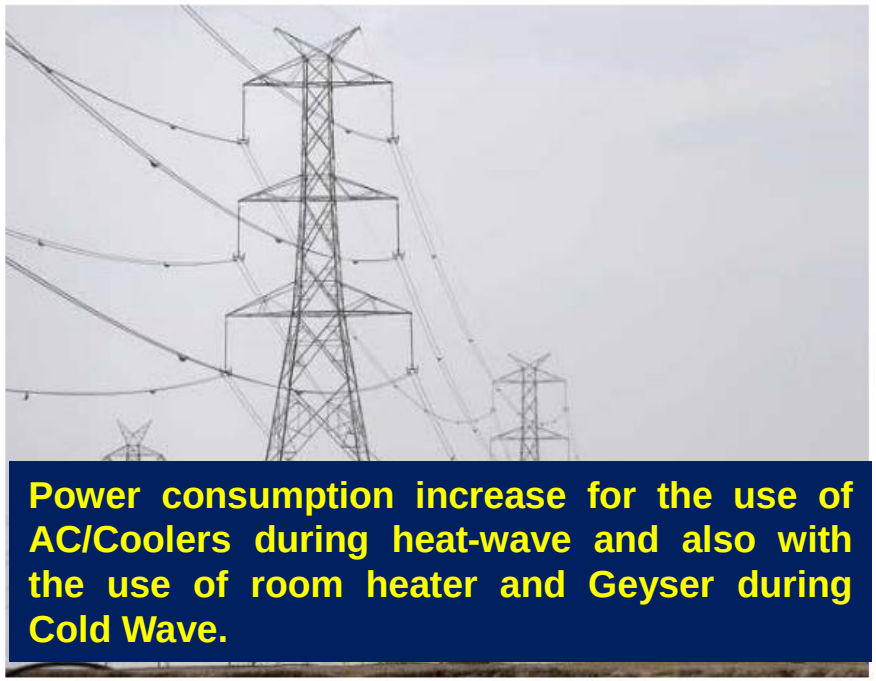
Energy sector and S2S prediction

Example: Increase of Temperature Increase of Power demand

Power demand in Delhi crosses 6,500 MW mark

The peak power demand in the national capital shot up to an all time high of 6,526 MW today, with many areas facing outages due to local faults as the heatwave condition continued in the city.

By: PTI | New Delhi | Published: June 6, 2017 10:27 PM

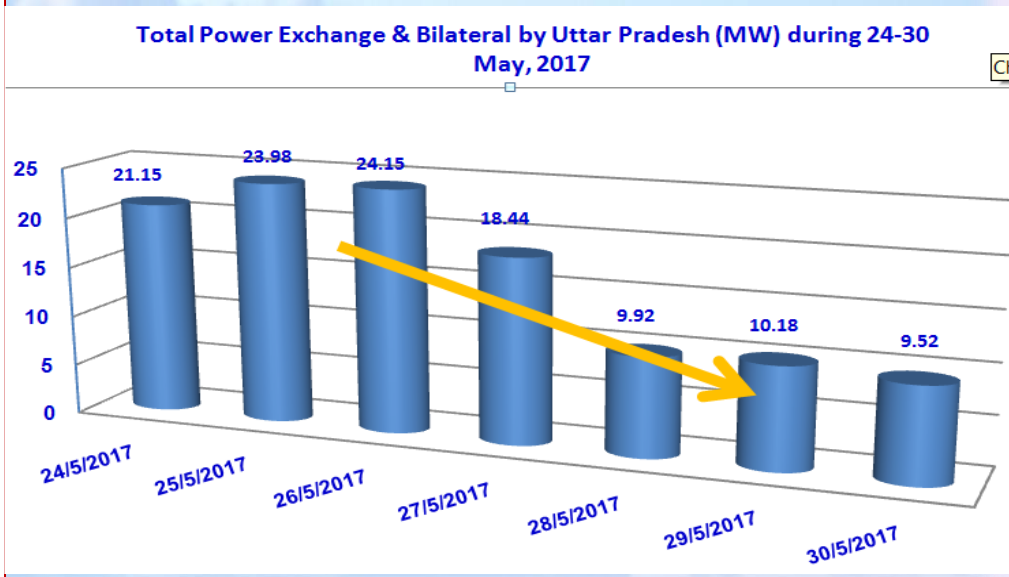


Power consumption increase for the use of AC/Coolers during heat-wave and also with the use of room heater and Geyser during Cold Wave.

The hot summer months this year have pushed the peak power demands to record levels, with April

Benefit achieved by Uttar Pradesh

Forecasts of rain and thunderstorm for 27/28/29-05-2017 helped in better load assessment As UP demand went down from 19000 MW to 17000 MW due to change in weather conditions, STOA & purchase from power exchange of 2000 MW was reduced i.e. backing down of approximately 13 MU of costly thermal generation.



Energy sector and S2S prediction

- Weather-related risk is primary driver for energy pricing, production & usage.
- As formal decision-making processes already exists within energy generation sector, it is easier to develop relationships with this sector than many other sectors with less formal practices.
- Routine practice for wind energy sector to use short-range wx forecasts.
- Energy demand scenarios based on ensemble predictions are more accurate up to 10 days in advance;
- S2S forecasts could be used to support it by hedging for anticipated energy peaks and other weather-related energy trading opportunities and risks.
- S2S wind speed forecasts can address challenge of intermittency by enabling transmission operators to plan further ahead and increase grid efficiency (Pinson, 2013), although at present only mean wind values (zonal and meridional) are available on the S2S timescale.

Energy sector and S2S prediction

- As S2S forecasts become more skilful and complete, grid operators may further optimize the applications relevant to supply (e.g. wind speed for wind power, precipitation and temperature for hydropower operations) and
- Prepare for increased utility demand using updated demand scenarios
- demand to inform switching on/off longer-start fuel sources e.g. nuclear.
- Challenge of balancing a fluctuating wind energy resource with more stable energy sources will grow over the time
- Manage distribution, transmission and maintenance scheduling to minimize disruption to power availability
- Adjust energy pricing and production to ensure power remains affordable

Emerging sectors and S2S Prediction

- Many other sectors could potentially benefit from skilful S2S forecasts
- S2S forecasts could be used to augment the existing use of seasonal environmental management forecasts, such as

❖ providing additional decision support information for marine fisheries and aquaculture (e.g. Spillman and Hobday, 2014)

❖ wildfire risk management (Owen et al., 2012). Similarly,

❖ Retail sector could be used for advanced stock orders where the timing of seasonal changes is important, or support preparedness ahead of extreme weather events such as heat waves (e.g. Hudson et al., 2015), tropical cyclones/floods (e.g. Vitart et al., 2010) and snow (e.g. Cohen, 2003)

(White et al, 2017)

Category	Challenges	Opportunities
Systematic model deficiencies	Systematic misrepresentation of coupled atmosphere–ocean feedbacks, which compounds existing errors or generate new biases. Persistent biases and errors remain in the climate models, as well as limited understanding of physical process	Continued investment in supercomputers, data collection and initiatives that support both further development and uptake of S2S forecasts, like WMO WWRP–WCRP S2S project and WMO GFCS
Quantifying uncertainty	Inherent errors & uncertainties in probabilistic prediction due to predictability limits & deficiencies in models & initialization	Use multimodel S2S datasets, to quantify forecast uncertainty in practical & relatively simple way
Forecast verification	Verification is critical in context of making S2S forecasts useful/usable for applications	Develop new seamless verification methods, e.g. time averaging windows (e.g. 1 week means 2 week means)

Category	Challenges	Opportunities
Awareness of S2S	Raising awareness of the 'new' S2S timescale, data availability and potential uses	Promote MME and S2S project repositories, integration of S2S forecasts into Regional Climate Outlook Forums
Case studies	Few 'success stories' of S2S predictions to support promotion of S2S forecasts and their integration into applications	Increase No. of case studies using S2S hind cast repositories, demonstrating retrospective forecast skill
Integration with social sciences to ensure forecasts are useful/usable	Little current understanding and characterizing of decision-making frameworks and processes at relevant spatial, temporal and end-user scales	Collaborate with social science communities to leverage existing knowledge on information creation, communication, use and valuation of S2S predictions

Summary

- Significant Progress on Operational S2S with MoES initiative and collaborative efforts of IMD, IITM, NCMRWF and INCOIS.
- Implementation and operationalization of coupled modelling system at IMD has led to the improvement of S2S Forecasting.
- ERF provides useful skill up to 2 to 3 weeks and products are being prepared for applications in Agriculture, Hydrology, Energy, Health and Disaster Management sectors.
- Skillful forecast of S2S can have the positive impact on economy
- Scope for utilisation of big data and latest tools like artificial intelligence and machine learning for
  - ❖ hazard monitoring and prediction and decision making,
  - ❖ suitable integration of data based tools with S2S prediction system
- There is scope to reach out to users with all end user options with respect to content, format, language, timeliness, robustness and quality of information in S2S timescale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Thank You